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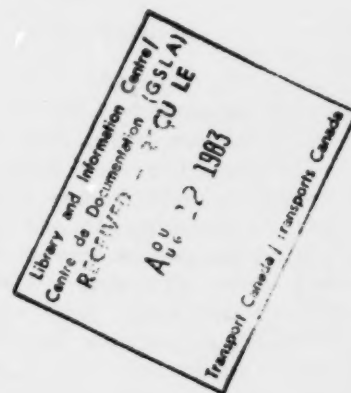
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GEOTEXTILES IN RAILWAY TRACK REHABILITATION APPLICATIONS

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in Railway Track Rehabilitation Applications

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17. Abstract Since about 1965 there has been a rapid increase in the use of geotextiles in civil engineering. Geotextiles have recently been introduced to the rail transportation industry to correct recurring track support problems. A wide range of geotextiles was observed to provide improvements in many short-term applications. Unfortunately, these improvements were not always longlasting. For longevity of the application, a much greater discrimination between geotextile types and materials was found to be required. Indeed, for long-term applications not only were the geotextile's individual properties found to be of importance, but also the choice of the correct construction procedure and the matching of the soil's engineering properties. Drainage was found to be the most critical aspect for achieving long-term stability in the track structure. Excess moisture within the roadbed was found to reduce the subgrade strength and provide easy access for fine-grain soils to foul the open ballast. Proper drainage techniques, combined with geotextiles, are given special consideration. Matching of the soil's characteristics with those of the geotextile was also found to be of importance, and laboratory test procedures to measure the properties of the geotextiles were developed and are appended. Conclusions are given regarding the further use of geotextiles in track rehabilitation and recommendations were made for further work in developing geotextile longevity of a rehabilitation.					
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17. Résumé L'emploi des géotextiles en génie civil a commencé à se généraliser rapidement vers 1965. Récemment, les chemins de fer en ont utilisé afin de résoudre certains problèmes chroniques concernant la stabilité des voies ferrées. On a constaté alors qu'il existe un grand nombre de ces géotextiles pouvant jouer un rôle utile dans des utilisations à court terme. Malheureusement, les améliorations apportées n'ont pas toujours un effet durable. On s'est donc aperçu que, pour obtenir des résultats à plus long terme, il fallait exercer un choix beaucoup plus sévère quant au type de géotextile à utiliser. En effet, lorsqu'on recherche une solution de longue durée, il faut tenir compte, non seulement des caractéristiques du géotextile lui-même, mais aussi de sa mise en oeuvre et de son adaptabilité aux propriétés mécaniques du sol. On a aussi constaté que le drainage est absolument essentiel à la stabilité et à la durabilité des voies ferrées. En effet, un excès d'humidité dans l'assise de la voie réduit la résistance mécanique de l'infrastructure et permet aux matières fines contenues dans cette dernière de venir contaminer le ballast. Les techniques de drainage associées à l'emploi de géotextiles ont été étudiées de très près. Autre aspect d'importance, la concordance qui doit exister entre les caractéristiques spécifiques des sols et des géotextiles utilisés; des méthodes d'essai en laboratoire visant à déterminer les caractéristiques de ceux-ci ont été développées. Elles figurent en annexe au rapport. Celui-ci se termine par des conclusions sur l'emploi plus poussé des géotextiles dans la restauration des voies ferrées et par des recommandations sur la poursuite des recherches visant à rendre ainsi ces restaurations plus durables.			
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TABLE OF CONTENTS

LIST OF TABLES	viii
LIST OF FIGURES	ix
LIST OF PLATES	xiv
1. INTRODUCTION	1
2. LITERATURE SEARCH AND SYNTHESIS	5
2.1 Introduction	5
2.2 Fabric Types	5
2.2.1 Fibres	5
2.2.1.1 Polypropylene	6
2.2.1.2 Polyethylene	6
2.2.1.3 Nylon	7
2.2.1.4 Polyester	7
2.2.2 Woven Fabrics	8
2.2.3 Non-Wovens	9
2.3 General Fabric Applications	10
2.3.1 Filtration	10
2.3.2 Drainage	11
2.3.3 Reinforcement	16
2.3.4 Separation	20
2.4 Testing Procedures	21
2.4.1 General Properties	22
2.4.2 Mechanical Properties	22
2.4.3 Hydraulic Properties	24
2.4.4 Durability or Wear	26
2.5 Present Uses of Fabric in Track	26
2.6 Bibliography	27
3. THEORETICAL CONSIDERATIONS	35
3.1 Introduction	35
3.2 Basic Functional Requirements	37
3.3 Engineering Properties Affecting Geotextile Performance	38
3.4 Geotextile Type	44
3.5 Polymer Type	45
3.6 Fiber Size or Denier	45
3.7 Geotextile Depth	46
3.8 Summary of Track Problems	46
3.9 Summary of Abrasion and Impact Tests	46
4. PRELIMINARY INVESTIGATION PROGRAM	55
4.1 Introduction	55
4.2 Preliminary Site Investigations	55
4.3 Preliminary Assessment	58
4.4 Detailed Site Investigation	60

5.	ASSESSMENTS OF CN SITES	63
5.1	Introduction	63
5.2	Sites Investigated	63
5.2.1	Dundas Subdivision MP 73.97, Clarke Side Road, London MP 5.1	63
5.2.2	Kingston Subdivision MP 218.18, Elmwood Drive, Belleville	69
5.2.3	Kingston Subdivision MP 213.45, Shannonville Road, Belleville	72
5.2.4	Napapadogan Subdivision MP 200.10, 200.40 and 204.78 near Quisibis, New Brunswick	75
5.3	Overall Performance	80
5.4	Geotextile Permeability Results	85
6.	ASSESSMENT OF CONRAIL'S LOUDONVILLE TEST	93
6.1	Introduction	93
6.2	Method of Inspection	93
6.3	General Details	94
6.4	Control Site without Geotextiles	97
6.5	Geotextiles Installed	99
6.5.1	Terrafix 370RS	99
6.5.2	Typar 3601	101
6.5.3	Mirafi 600X	102
6.5.4	Bidim C-38	104
6.5.5	Bidim C-34	105
6.5.6	True Tex VT5000	105
6.5.7	Supac 5P	107
6.5.8	Typar 3801	108
6.6	Comparison of Cut Sections With and Without Geotextiles	109
6.7	Overall Performance	110
6.8	Lateral Permeability Tests	112
6.9	Oven Drying of Geotextiles	113
7.	ASSESSMENT OF CONRAIL'S SALEM TEST	121
7.1	Introduction	121
7.2	General Details	121
7.3	Control Site Without Geotextiles	123
7.4	Geotextiles Installed	123
7.4.1	Fibretext 300 or Crown Zellerbach 300	123
7.4.2	Bidim C-42	124
7.4.3	True Temper 700	125
7.4.4	Terrafix 814B	126
7.4.5	True Temper 900	127
7.4.6	Terrafix 400NR	128
7.5	Overall Performance	130
7.6	Permeability Test Results	131

8.	INSTALLATION PROCEDURE	137
8.1	Introduction	137
8.2	Location of Geotextiles	137
8.3	Shoulder Removal for Drainage	137
8.4	Installation Below Local Ground Level	138
8.5	Installation at Grade Crossings	139
8.6	Methods of Installing Geotextiles	140
8.7	Depth of Installation	141
8.8	Cost-Benefit of Installation	142
9.	SUMMARY AND CONCLUSIONS	147
9.1	Summary	147
9.2	Conclusions	148
10.	SUGGESTIONS FOR FURTHER STUDY	151
	REFERENCES	153
	APPENDIX A - DEVELOPED LABORATORY TESTS FOR GEOTEXTILES	
	APPENDIX B - PRELIMINARY SITE INVESTIGATIONS	

LIST OF TABLES

3.1	Problems Associated with Geotextiles for Track Maintenance .	47
3.2	(a) Evaluation of Geotextile Performance in Laboratory Testing	49
	(b) Description of Abrasion Processes	50
4.1	Preliminary List of Geotextile Site Installations	56
4.2	Assessment of the Preliminary Site Investigations	59
5.1	Effect of Depth on Wear in Worst 300 mm x 300 mm Geotextile Area	82
5.2	Holes Apparent in Ultrasonically Cleaned Geotextile Appearing Intact When Dirty	83
5.3	Ballast Data Adjoining Geotextiles and Permeability Data for Tests with 112 kPa Normal Load	87
6.1	Some Properties of Geotextiles In-Track at Loundonville, Ohio	98
7.1	Some Properties of Geotextiles In-Track at Salem, Ohio . . .	122

LIST OF FIGURES

1.1	Association of American Railroad's yearly data on average freight car capacity and load which both show a rapid increase since the early 1960's	2
2.1	French drain constructed with a fabric	13
2.2	Trench drain constructed with a fabric	13
2.3	Fabric wound around the pipe	13
2.4	Base course drain constructed with two layers of fabric . .	14
2.5	Drain with fabric behind a retaining wall	14
2.6	Filter fabrics used around drain in high embankments . . .	14
2.7	Use of fabric for vertical retaining wall	15
2.8	Procedure for installation of the vertical fabric strips .	15
2.9	Horizontal drains in embankment	16
2.10	Retaining structures application	17
2.11	Failure mass concept of fabric-reinforced soils - retaining structures	17
2.12	Embankment reinforcement application	18
2.13	Failure mass concept of fabric-reinforced soils - embankments	18
2.14	Low fill on soft foundation reinforcement application . . .	18
2.15	Subgrade stabilization application	19
2.16	Fabric in a rutted roadway section, section through rutted roadway	20
2.17	Fabric in a rutted roadway section, rut section free body indicating major forces	20
3.1	Typical effects of moisture on the strength of wood	36
3.2	Effect of wear on tensile tester modulus	43
5.1	Site plan of Clarke Side Road grade crossing (Dundas Subdivision MP 73.97)	65

5.2	Soil profile observed under tie at northwest corner of Clarke Side Road grade crossing, 1 m west of signal light, London Site A (Dundas Subdivision MP 73.97)	66
5.3	Soil profile observed under tie at northwest corner of Clarke Side Road grade crossing, 13 m west of signal light, London Site B (Dundas Subdivision MP 73.9)	66
5.4	Grain size analysis of soil samples from Clarke Side Road crossing, London Site A (Dundas Subdivision MP 73.97) . . .	66
5.5	Grain size analysis of soil samples from Clarke Side Road crossing, London Site B (Dundas Subdivision MP 73.97) . . .	66
5.6	Site plan of Elmwood drive grade crossing (Kingston Subdivision MP 218.8)	69
5.7	Soil profile observed under tie at southeast corner of Elmwood Drive grade crossing adjacent signal light, Belleville Site A (Kingston Subdivision MP 218.18)	70
5.8	Soil profile observed under tie at northwest corner of Elmwood Drive grade crossing adjacent signal light, Belleville Site A (Kingston Subdivision MP 218.18) . . .	70
5.9	Grain size analysis of soil samples from Elmwood Drive crossing south track, Belleville Site B (Kingston Sub- division MP 218.18)	70
5.10	Grain size analysis of soil samples from Elmwood Drive crossing north track, Belleville Site B (Kingston Sub- division MP 218.18)	70
5.11	Soil profile observed under tie at northwest corner of Shannonville Road grade crossing 1 m west of end of crossing planks, Belleville Site C (Kingston Subdivi- sion MP 213.45)	74
5.12	Grain Size analysis of soil samples from Shannonville Road crossing north track, Belleville Site C (Kingston Subdivision MP 213.45)	74
5.13	Soil profile observed under tie at private road crossing located about 8 km east of Quisibis, N.B., Site B (Napadogan Subdivision MP 200.1)	75
5.14	Soil profile observed under tie at private road crossing located about 7 km east of Quisibis, N.B., Site B (Napadogan Subdivision MP 200.4)	75

5.15	Grain size analysis of soil samples from crossing near Quisibis, N.B., Site A. (Napadogan Subdivision MP 200.1)	75
5.16	Grain size analysis of soil samples from crossing near Quisibis, N.B., Site B. (Napadogan Subdivision MP 200.4)	75
5.17	Comparison of grain size analysis of the two upper samples from Quisibis, N.B., Sites A and B (Napadogan Subdivision MP 200.1 and 200.4)	79
5.18	Soil profile observed under tie at grade crossing in Quisibis, N.B., Site C (Napadogan Subdivision MP 204.78)	79
5.19	Grain size analysis of soil samples from crossing in Quisibis, N.B., Site C (Napadogan Subdivision MP 204.78)	79
5.20	Comparison of grain size analysis of the two upper samples from Quisibis, N.B., Sites B and C (Napadogan Subdivision MP 200.4 and 204.78)	79
5.21	Measured geotextile worn through damage related to depth for Terrafix 300 type geotextiles	84
5.22	Results of lateral permeability on geotextiles recovered from CN tracks	86
6.1	Schematic plan and topography of the Loudonville geotextile test site	95
6.2	Cross sections along Loudonville geotextile site	96
6.3	Grading curves of ballast samples recovered from control site established during the October 1981 visit	99
6.4	Grading curves of ballast samples recovered from Terrafix 370RS installation excavated during May 1981 visit	100
6.5	Grading curves of ballast samples recovered from Typar 3601 installation excavated during May 1981 visit	101
6.6	Grading curves of ballast samples recovered from Mirafi 600X installation excavated during May 1981 visit	103
6.7	Grading curves of ballast samples recovered from Bidim C-38 installation excavated during May 1981 visit	104
6.8	Grading curve of ballast samples from rail seat and trapped fines removed from the True Tex VT5000 recovered from track centreline during May 1981 visit	106

6.9	Grading curve of trapped fines removed from the True Tex VT5000 recovered from track shoulder during May 1981 visit	106
6.10	Grading curves of ballast samples recovered from Supac 5P installation excavated during May 1981 visit	108
6.11	Grading curves of ballast samples recovered from Typar 3801 installation excavated during May 1981 visit	109
6.12	Lateral permeability of as-recovered, cleaned and new True Tex VT5000 geotextile from two-layered centreline material	112
6.13	Lateral permeability of as-recovered, cleaned and new True Tex VT5000 geotextile from single-layered shoulder material	112
7.1	Grading curve of trapped fines removed from geotextile Fibretex 300 recovered during May 1981 visit	124
7.2	Grading curve of trapped fines removed from geotextile Bidim C-42 recovered during May 1981 visit	125
7.3	Grading curve of trapped fines removed from geotextile True Temper 700 recovered during May 1981 visit	126
7.4	Grading curve of trapped fines removed from geotextile Terrafix 814B recovered during May 1981 visit	127
7.5	Grading curve of trapped fines removed from geotextile True Temper 900 recovered during May 1981 visit	128
7.6	Grading curve of trapped fines removed from geotextile Terrafix 400NR and ballast samples recovered during May 1981 visit	129
7.7	Permeability test results on geotextile samples recovered from centre of track during May 1981 visit	130
8.1	Illustration of geotextile installation at grade crossing .	140
10.1	Multi-layer geotextile, needle-punched together into single unit	152
A.1.1	Fabric clamp for EOS test	A.2
A.1.2	Sample report form	A.6
A.2	Apparatus for ballast impact test	A.7
A.3	Permeability mold for lateral permeability test	A.11

A.4	Apparatus for tensile rupture test	A.15
A.5	Apparatus for aggregate abrasion test	A.19
A.6	Apparatus for capillarity test	A.22

LIST OF PLATES

3.1	Pumping of fill 1.5 m (5 ft) thick placed over swamp subgrade	52
3.2	Plastic flow on low rail from slow order imposed due to pumping track	52
3.3	Bent rail resulting from pumping at joints	52
3.4	Laboratory-fouled new geotextile (left) and same brand track-fouled (right)	52
3.5	Typical microscopic view of resin-dipped geotextile showing 6 denier fibre (left), 15 denier fibre (right) . .	53
3.6	Results of Taber Abrador using 10,000 cycles of CS-17 stone with 1000 g weights	53
3.7	Typical microscopic view of heat-bonded geotextile showing flattened condition of fibre matrix	53
5.1	General conditions and location of test pits at Clarke Side Road, London, grade crossing (Dundas Subdivision MP 73.97) .	88
5.2	Soil profile at Clarke Side Road, London Site A, having geotextile (Dundas Subdivision MP 73.97)	88
5.3	Soil profile at Clarke Side Road, London, Site B without geotextile (Dundas Subdivision MP 73.97)	88
5.4	Condition of geotextile at Clarke Side Road, London Site A (Dundas Subdivision MP 73.97)	88
5.5	Condition of fouled ballast in contact with tie base at Elmwood Drive grade crossing, Belleville Site A (Kingston Subdivision MP 218.18)	89
5.6	Condition of ballast below rail seat and end of tie at Elmwood Drive, Belleville Site A, showing fouling by silt and clay particles (Kingston Subdivision MP 218.18)	89
5.7	Condition of geotextile at Elmwood Drive, Belleville Site A (Kingston Subdivision MP 218.18)	89
5.8	Filter cake formation below geotextile at Elmwood Drive, Belleville Site A (Kingston Subdivision MP 218.18)	89

5.9	Condition of ballast below rail seat and tie centreline at Elmwood Drive, Belleville Site B (Kingston Subdivision MP 218.18)	90
5.10	Surface condition and fouling of ballast at Shannonville Road grade crossing, Belleville Site C (Kingston Subdivision MP 213.45)	90
5.11	Perched water trapped 50 mm above geotextile at Shannonville Rd, Belleville Site C (Kingston Subdivision MP 213.45)	90
5.12	Ballast, subballast and subgrade below rail seat with shovel at tie centreline of grade crossing, 8 km east of Quisibis, Site A (Napadogan Subdivision MP 200.1)	90
5.13	Excavation to locate geotextile depth prior to pit excavation at Quisibis Site A (Napadogan Subdivision MP 200.1)	90
5.14	Condition of geotextile and filter cake formation at Quisibis Site A (Napadogan Subdivision MP 200.1)	90
5.15	Test pit and soil profile at grade crossing 7 km east of Quisibis, Site B (Napadogan Subdivision MP 200.4)	91
5.16	Condition of geotextile at grade crossing in Quisibis, Site C (Napadogan Subdivision MP 204.78)	91
5.17	Comparison of new (left) and used geotextile material backlighted so as to show high density of fibres in new material versus particle penetration and internal wear of used material	91
6.1	View of south track looking westward away from geotextile installation, showing approach embankment (foreground) and cut section (background) undercut at same time as geotextile installation section	114
6.2	View of south track looking westward, taken from ditch at same chainage as Plate 6.1	114
6.3	View of south track looking eastward along section containing geotextiles, taken from same chainage as plates 6.1 and 6.2	114
6.4	View of south track looking eastward, taken from ditch at same chainage as Plate 6.3	114
6.5	General view of test pit excavation of control site at 1+44 just prior to start of geotextile test installations .	114

6.6	From centreline of track showing upward migration of what remains of sand subballast and upward migration of dark subgrade soil	114
6.7	View of west wall below rail seat of control site test pit taken from centreline of track	115
6.8	View of west wall below rail seat of control site test pit taken from shoulder of track	115
6.9	Condition of west wall, geotextile and ballast below geotextile during May 1981 excavation of Terrafix 370RS at 1+76.5	115
6.10	General view of east wall below rail seat and end of tie during October 1981 excavation of Terrafix 370RS at 1+86.1	115
6.11	Condition of geotextile and ballast below geotextile during October 1981 excavation of Terrafix 370RS	115
6.12	Visual condition of terrafix 370RS from excavation made October 1981	115
6.13	Condition of east wall below rail seat and end of tie during October 1981 excavation of Typar 3601 at 4+88.5	116
6.14	Condition of Typar 3601 below rail seat during October 1981 excavation	116
6.15	Surficial subsidence evident during October 1981 visit as a track entered and went through cut section. Personnel in background are at Mirafi 600X location 7+54.5	116
6.16	Close up to surficial subsidence evident during October 1981 visit at approximately 6+00	116
6.17	Slurried fines observed below monofilament woven Mirafi 600X during May 1981 visit	116
6.18	Condition of east wall and subsidence observed at the geotextile elevation showing water trapped within the roadbed at the October 1981 excavation of Mirafi 600X	116
6.19	Condition on wall excavated 300 mm (12 in) below Mirafi 600X elevation showing no subballast and very bad fouling by subgrade during October 1981 visit	117
6.20	Condition of geotextile Mirafi 600X observed during October 1981 visit	117

6.21	Signs of pumping occurring at surface of track during October 1981 visit near Chainage 9+00 above installed Mirafi 600X	117
6.22	Condition of east wall and subsidence observed at the geotextile elevation showing water trapped within the roadbed at the October 1981 excavation of Bidim C-38 . . .	117
6.23	Condition of geotextile Bidim C-38 observed during October 1981 visit	117
6.24	Condition of west wall and relatively dry geotextile elevation observed at May 1981 excavation of Bidim C-38 . .	117
6.25	Condition of west wall and ballast below geotextile during May 1981 excavation of True Tex VT5000	118
6.26	Condition of geotextile True Tex VT5000 observed at October 1981 visit	118
6.27	Partially-stained condition of lower surface and cake formation below True Tex VT5000 observed at October 1981 visit	118
6.28	Condition of east wall of excavation extended below ties during October 1981 inspection of VT5000 installation . . .	118
6.29	Sand subballast cake formation below VT5000 observed during October 1981 visit	118
6.30	Condition of west wall above Supac 5P taken from track centreline during October 1981 visit	118
6.31	Condition of geotextile Supac 5P and underlying ballast observed during October 1981 visit	119
6.32	Condition of westbound track which did not contain geotextiles and was not subject to undercutting in November 1979, observed during May 1981 visit	119
6.33	Condition of geotextile Typar 3801 observed during May 1981 visit	119
6.34	Wet condition of fouled ballast and geotextile Typar 3801 at geotextile elevation during October 1981 visit	119
6.35	Condition of east wall showing dirty wet ballast below rail seat and subsidence below track at geotextile elevation during excavation of Typar 3801, October 1981 . .	119

6.36	General view of drainage and south track surface conditions through cut situated immediately west of main test area at MP155, observed October 1981	119
6.37	Pumping track surface of south track west of MP155 undercut October 1979 at same time as geotextiles were installed in section just east of MP155, observed October 1981	120
6.38	Close-up of typical pumping seen in Plate 6.37, also showing shallow drainage ditch, observed October 1981 . . .	120
6.39	Particularly bad pumping track seen on south track viewed in Plate 6.37, observed October 1981	120
7.1	Conrail's geotextile test site at Salem, Ohio, looking westward, showing drainage ditch, closeness of excavated ties and Elsworth Street grade crossing in background . . .	134
7.2	Condition of ballast next to rail seat at control site without geotextile during October 1981 visit	134
7.3	Close-up of west wall of control site excavation, showing undercutting demarkation between old dirty ballast and new make-up ballast with some fouling of new ballast evident, observed October 1981	134
7.4	Damage of geotextile due to tamper tines agitating ballast which abraded geotextile Fibertex 300, observed during May 1981 visit	134
7.5	Retention of fouled ballast fines by Bidim C-42 and fouling below rail seat above damaged geotextile, observed on west wall of excavation made during October 1981 visit .	134
7.6	Condition of west wall of excavation above True Temper 700, also showing abraded geotextile damage from tamper-agitated ballast particles observed during October 1981 visit	134
7.7	Abrasion and elongation of geotextile True Temper 700 caused by ballast tamping observed during May 1981 visit .	135
7.8	Condition of west wall of excavation above Terrafix 814B, also showing fines retained by geotextile, observed during October 1981 visit	135
7.9	Abrasion of geotextile Terrafix 814B caused by tamper agitation of ballast particles, observed during October 1981 visit	135

7.10	Moist condition of excavation above True Temper 900 as observed during October 1981 visit	7.15
7.11	Condition of geotextile True Temper 900 showing small abrasion/puncture holes observed during October 1981 visit	7.15
7.12	Damage from tamper tine penetration of geotextile Terrafix 400NR along with abrasion damage below tie area, presumably caused from agitation of ballast particles observed during October 1981 visit	7.15
7.13	Tamper tine penetration holes created on surface of dirty ballast left in place from undercutting as observed during October 1981 visit	7.16
7.14	Shoulder drainage conditions, looking eastward along eastbound track ditch with station building in upper right corner	7.16
8.1	Typical grade crossing installation inspected with excavation width close to tie width	8.7
8.2	Discharging undercut dirty ballast on track shoulder helps foul shoulder ballast. Both should be levelled to trench undercut elevation to facilitate drainage from track bed .	8.7
8.3	Typical fouled grade crossing with inadequate drainage at centreline of crossing highway	8.7
8.4	Small perforated pipe used to maintain long-term drainability of track and grade crossing through track shoulders	8.7
8.5	Geotextile turned downward at end of grade crossing to allow gravitational drainage of track bed through track shoulders and/or laterally along geotextile	8.7
8.6	Bath tub effect produced by not removing track shoulders during grade crossing upgrading	8.7
8.7	Canal effect created by undercutting operation where shoulder ballast is not removed	8.8
8.8	Geotextile roll attached to undercutter	8.8
8.9	Laying equipment for use with heavyweight geotextiles . . .	8.8
8.10	Rear view of heavyweight geotextile laying equipment . . .	8.8
8.11	Geotextile roll being manually laid	8.8

8.12	Ballast-aggregate-worn holes through 700 g/m ² (20 oz/yd ²) geotextile made by tamper agitation of ballast	8.8
8.13	Track being supported by old ties while ballast train deposits new aggregate	8.9
8.14	Ballast train on track being supported above geotextile by short lengths of old ties	8.9
8.15	Rail jack used to support track during ballasting	8.9
B.1	General view of grade crossing taken from north of tracks, looking west (Oakville Subdivision MP 21.96)	B.21
B.2	Submerging ties and running rail of lower (north) track resulting from poor drainage (Oakville Subdivision MP 21.96)	B.21
B.3	General view looking east along eastbound main line, showing flat terrain and two siding tracks on south side (Oakville Subdivision MP 24.42)	B.21
B.4	Poor surface drainage conditions for eastbound main line (Oakville Subdivision MP 24.42)	B.21
B.5	General view of crossing looking east, showing flattish nature of surrounding terrain (Kingston Subdivision MP 218.18)	B.21
B.6	Shallow drainage conditions at southeast shoulder of crossing (Kingston Subdivision MP 218.18)	B.21
B.7	Fouled ballast on surface of northwest corner of crossing (Kingston Subdivision MP 218.18)	B.22
B.8	Geotextile installation at east switch, track 3 (Kingston Subdivision MP 218.18)	B.22
B.9	Close-up view of switch (Kingston Subdivision MP 218.18)	B.22
B.10	Track conditions in cut section (Kingston Subdivision MP 221.34)	B.22
B.11	Geotextile with turned down ends beyond crossing to facilitate lateral drainage through geotextile (Kingston Subdivision MP 221.34)	B.22
B.12	General site conditions showing extensive ballast fouling beyond rehabilitated crossing (Alexandria Subdivision MP 22.29)	B.22

B.13	View of track shoulder with perforated drain pipes (Alexandria Subdivision MP 22.29)	B.23
B.14	General view showing fouled ballast conditions on east side of grade crossing (Alexandria Subdivision MP 58.70)	B.23
B.15	Drainage conditions on west side of grade crossing which was showing less ballast fouling than on east side (Alexandria Subdivision MP 58.70)	B.23
B.16	Drainage conditions at grade crossing showing pumping track beyond rehabilitated area (Alexandria Subdivision MP 65.93)	B.23
B.17	View of track shoulder with perforated drain pipe (Alexandria Subdivision MP 65.93)	B.23
B.18	Conditions of upgraded main line (left) track (Alexandria Subdivision MP 67.44)	B.23
B.19	View of track shoulder and drainage conditions at grade crossing with obvious pumping beyond crossing (Alexandria Subdivision MP 67.44)	B.24
B.20	Flat terrain at grade crossing and along track (Alexandria Subdivision MP 68.94)	B.24
B.21	Pumping track conditions just beyond grade crossing (Alexandria Subdivision MP 68.94)	B.24
B.22	General site conditions at Clarke Side Road grade crossing (Dundas Subdivision MP 73.97)	B.24
B.23	Close-up of track which was later selected for test pit excavations (Dundas Subdivision MP 73.97)	B.24
B.24	General site conditions at Massena grade crossing (Massena Subdivision MP 52.13)	B.24
B.25	Close-up view of crossing showing geotextile in foreground (Massena Subdivision MP 52.13)	B.25
B.26	General conditions looking southeast along track (Napadogan Subdivision MP 200.0)	B.25
B.27	Southwest view of track embankment and ditch from northeast side (Napadogan Subdivision near MP 200.1)	B.25
B.28	Northwest view of track embankment and ditch from southeast side (Napadogan Subdivision near MP 200.1)	B.25

B.29	General conditions at MP 200 looking northwest along track (Napadogan Subdivision MP 200)	B.25
B.30	General conditions at MP 201 looking northwest along track (Napadogan Subdivision MP 201)	B.25
B.31	General view of grade crossing on main tracks (right) looking northeast (Napadogan Subdivision MP 203.20)	B.26
B.32	General view of track conditions looking to the southeast with main line on left (Napadogan Subdivision MP 203.20) .	B.26
B.33	General site conditions at minor road crossing (Napadogan Subdivision MP 204.78)	B.26
B.34	Close-up view of ballast condition at minor road crossing (Napadogan Subdivision MP 204.78)	B.26
B.35	General site conditions at logging road crossing (Napadogan Subdivision MP 204.78)	B.26
B.36	Close-up view of ballast condition at logging road crossing (Napadogan Subdivision MP 204.78)	B.26

CHAPTER 1

INTRODUCTION

Since about 1965, there has been a rapid increase in the use of industrial fabrics or geotextiles in civil engineering. The initial growth has been in three general areas of application: erosion control, subsurface drainage and soil reinforcement of the base of newly constructed fills. The more common applications in each area are: revetment designs for waterfront structures, underground drainage systems such as French drains or wrapped conduits, and embankments constructed on soft subgrade soils such as weak clays or peat deposits.

These three areas of application have provided the textile industry with a good market for their products. The manufacturers have developed a wide range of geotechnical fabrics, more commonly known as geotextiles, to suit the specific needs of the design engineer. Unfortunately many of these geotextiles are sold and used without the salesperson or designer understanding the significance of the various geotextiles' characteristics or properties. Prior to use, it should be the engineer's responsibility to be familiar with the behaviour of different geotextiles in order to select a material that will match the engineer's particular design needs.

Geotextiles have recently been introduced to the rail transportation industry in North America in order to correct some of the problems related to railroad track support. Similar problems have occurred in Japanese and European track which are subjected to lighter axle loads. Most of the problems can be related to inadequate track drainage, whether because of topography or because of created drainage problems. These problems have been aggravated by the use of heavier cars and unit train systems resulting in higher average freight car capacity and higher freight car use as demonstrated by the Association of American Railroads data shown in Figure 1.1. The combined effect of an increased wheel load over a longer repetitive cycle has created additional strain on the structure, resulting in more frequent track repairs, particularly in areas of poor drainage.

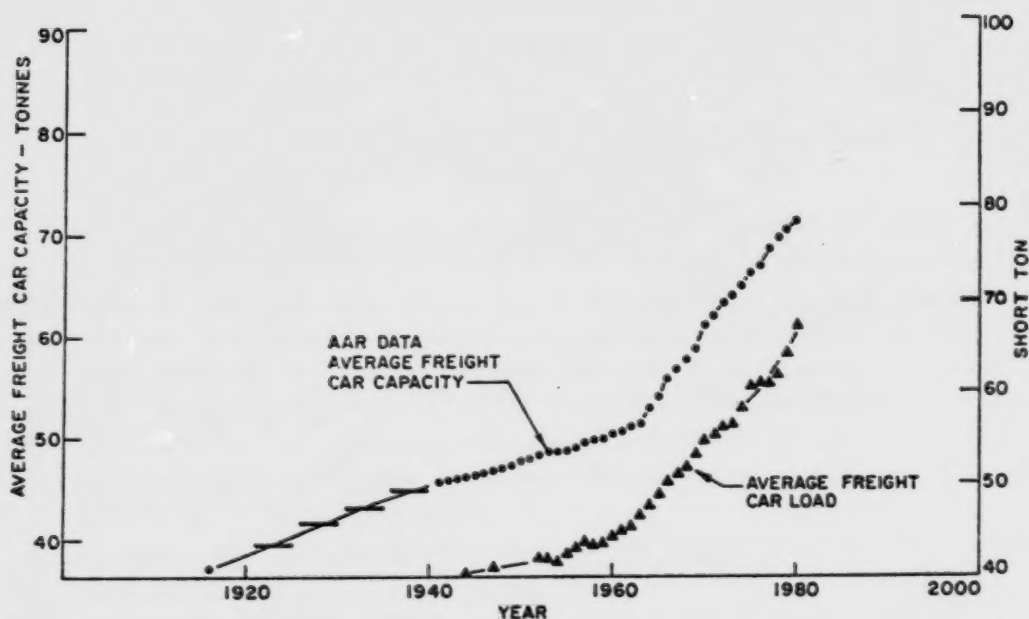


Figure 1.1 Association of American Railroad's yearly data on average freight car capacity and load which both show a rapid increase since the early 1960's

The cost effect of increased maintenance on existing track has prompted the railroads to incorporate the use of geotextiles in many of their rehabilitation programs. Initially, the technical recommendations for selecting the proper geotextile and installing it in-track were adapted from other non-railroad proven applications. Experience is now indicating that the track environment is much more abrasive and demanding on geotextiles than originally thought. Consequently, the present study was established to develop guidelines for the use of geotextiles in railway track rehabilitation applications. The areas considered herein are:

- . establishment of attributes for geotextile selection and installation during track rehabilitation programs,
- . evaluation of the condition of a number of geotextiles in-track
- . identification of the types of track structures or problems that may benefit or be corrected by the use of geotextiles.

To do this, a laboratory testing program was developed at Queen's University and a field site investigation program was organized in cooperation with Canadian National Railways, with the intention of visiting a number of locations where geotextiles were previously installed to assess their performance in-track. The field program has concentrated its efforts on geotextile installations associated with track rehabilitation problems, including those in the immediate area of the ballast and subballast. The study does not examine the problems associated with geotextiles installed at the subgrade level for soil reinforcement or for French drains, since these requirements are likely to be similar to those of other transportation support systems extensively under study by highway and airport authorities.

Prior to the start of the technical research, a literature review was undertaken by Mrs Carolyn Fitzpatrick of CIGGT. This review and synthesis of the literature, along with a comprehensive bibliography, are contained in Chapter 2. Since the review contains concepts in vogue prior to the technical research reported herein, there are some cases where this earlier work contradicts the present findings. Consequently, the ideas reported in Chapter 2 should be treated with some caution, particularly where they are at variance with current findings.



CHAPTER 2

LITERATURE SEARCH AND SYNTHESIS*

2.1 INTRODUCTION

The most comprehensive piece of work available in the literature on geotextiles is Evaluation of Test Methods and Use Criteria for Filter Fabrics by J.R. Bell, Oregon State University, Cornwallis, Oregon. Any review of the literature on filter fabrics should begin with this very comprehensive work. Considerable other literature exists, but much of the available information is qualitative rather than quantitative, and so does not lead to the development of effective design procedures. Many of the tests currently applied to geotextiles have been adapted from techniques developed for other purposes, so that there is a definite requirement for development of tests that adequately model fabric behaviour in the track environment.

2.2 FABRIC TYPES

Two major types of geotextiles are on the market at present -- wovens and non-wovens. This distinction is based on their type of manufacture. There are three major manufacturing subsections into which non-wovens may be subdivided: needle-punched, heat-bonded, or resin-bonded needle-punched. Combination geotextiles are also available. Finally, both wovens and non-wovens can be subdivided into the polymer type for the fibre from which they are manufactured.

2.2.1 Fibres

Four major polymers are used in the production of 'geotextiles'. A polymer is basically formed from a series of long-chained molecular structures. These are extruded in a liquid state to form fibres which can then be used to produce fabrics. The extrusion process can be used to control the thickness of the fibres, and in many cases the resulting fibre is often subsequently stretched to control the thickness even further. This process can also be used to control the strength-to-stretch relationship of the fibre.

* This review contains concepts in vogue prior to the research reported in the rest of this report, and in some cases contradicts present findings. Consequently, the ideas reported here should be treated with caution, particularly where they are at variance with current findings.

Those polymers most often used for 'geotextiles' are polypropylene, polyethylene, polyamide (nylon) and polyester. Many products use them in combination, either in the fabric construction or right at the extrusion stage. In the latter case, two polymers can be extruded side by side or homogeneously mixed together before extrusion. Some fibres are also produced with a coaxial type of construction, using different types of polymer for the core and the sheath of the fibre.

All polymers used for geotextiles suffer from deterioration when exposed, long term, to ultraviolet light (sunlight), but may be stabilized using carbon black to give a controlled lifetime. Elevated temperature has an adverse effect on all polymers with regard to most material properties.

2.2.1.1 Polypropylene

This polymer has a density of 0.91, and will float on water. It has a low rate of water absorption, good flexibility and good resistance to acids and alkalies.

Polypropylene is considered rot-proof to biological attack, but it does not show good resistance to abrasion and also creeps under stress. This characteristic is well exhibited in its stress-strain relationship, which increases to a peak stress at a yield strain, but which then continues to a higher strain for decreasing stress, and exhibits very high values of strain before failure. This feature does, however, contribute to polypropylene's high resistance to cutting under impact loading, such as falling rocks.

2.2.1.2 Polyethylene

At present this polymer is not widely used for construction fabrics in North America, but this is not the case in Europe or Japan, where the use is significant. Like polypropylene, it is a lightweight fibre with low water absorption, and good chemical resistance. It retains its flexibility at quite low temperatures, but again like polypropylene does not have the higher strengths of polyester or nylon.

2.2.1.3 Polyamide

This polymer has mechanical characteristics of high strength with low strain, and high resistance to abrasion when new. With polyester, nylon shares a higher resistance to deterioration in sunlight than either polypropylene or polyethylene, and also a higher fibre melting point. However, as does polyester and polypropylene, nylon develops its fibre structure during the manufacture of the filaments. Drawing after cooling results in a type of work hardening, giving the fibre its mechanical durability. Of the polymers considered here, nylon has the greatest capacity to absorb water, and this can result in a reduction in strength at ambient temperatures in earthworks.

2.2.1.4 Polyester

Polyester shares with nylon good mechanical properties, high strength with low elongation at rupture, and high resistance to abrasion. Also like nylon, it has a higher melting point and good creep characteristics. A high modulus of elasticity also gives it good resistance to impact forces. The polymer's characteristics appear to be unaffected by water.

Of those fibres mentioned here, the two with the stronger mechanical properties, nylon and polyester, are also the most expensive. Where strength is the optimum requirement, however, their higher strength-to-weight ratio might well make them competitive with the other, cheaper, fibres. Where bulk is of prime importance, however, the polypropylenes and polyethylenes are not only less expensive per pound, but also provide more bulk per pound.

While the emphasis, so far, in this brief summary has been placed on the differences between the different polymer types, it should be noted that considerable differences in characteristics can be achieved within individual polymer groups, and the previous discussion should be taken as very general indeed. The properties of a polymer can be altered with changes to its chemical composition, and by the method of forming used to produce the fibre filament. The modulus of elasticity of polyester, for example, can be varied by as much as a factor of five. The fibres themselves can also then be used in a variety of processes to manufacture a fabric.

2.2.2 Woven Fabrics

The most conventional method of fabric production is weaving, where the traditional method of interlacing filaments at right angles to each other is used. Those filaments in the longitudinal direction are called the warp, and those at right angles the weft or fill. Different patterns of interlacing the weft and the warp can be used to produce different surface finishes and to vary the relative porosities of the fabrics.

Plain weave is most common amongst woven construction fabrics. The weaving process is relatively expensive, but does have the advantage of producing a product with fairly uniform characteristics. The pore size of the woven fabric is particularly easy to determine and is relatively uniform. However, a woven fabric's mechanical properties are not isotropic. The warp and fill fibres, although of the same polymer, may have different strengths, or may even not be of the same polymer. The type of weave used may also affect the directional strengths. The stress/strain characteristics in the cross warp and fill directions can therefore be significantly different. Materials woven in a right angle configuration strain differentially at 45° to the fiber directions.

A final differentiation can be made amongst woven fabrics by considering the composition of the fibre used to produce them. The polymer filament produced can be used in a number of ways. The heavier diameter filaments can be used singly to produce a monofilament fabric. Owing to their relatively large filament size, these fabrics are most suited to the use of carbon black for ultraviolet light stabilization. However, monofilament fibres cannot be drawn, so that the polymer does not achieve its maximum strength or modulus.

The high-strength woven fabrics, mostly recommended for use in the reinforcement function, are produced by using multifilament fibres. These are formed by many finely drawn polymer filaments. These pre-stressed fibres achieve an optimum molecular orientation and associated high strength. Due to the small filament diameter, however, these fibres cannot be stabilized by the carbon black method, and thus in use must be protected from any extensive exposure to ultraviolet light.

The cheapest form of woven fabric is produced with the use of split-film fibres, the most common form at present being split-film polypropylene. The fabric is woven of ribbons of very thin polypropylene sheet. This produces an inexpensive fabric of moderate strength and modulus.

2.2.3 Non-Wovens

These fabrics are composed of a generally random arrangement of fibres which are bonded together to form a fabric. In North America the fibres used are usually polyester, polypropylene or polyamide. The fibre filaments used are either continuous, as greater than 0.3 m in length, or staple, as ≥ 0.02 m typically. The fibres are laid in some way to provide a fabric mat. When continuous fibres are used, a mechanical process takes the fibre after extrusion and drawing and lays it randomly on a moving belt. When staple fibres are used, the fibres are either air blown onto a supporting screen or wet-laid in a fibre/water slurry. The randomness of the fibre arrangement in the fabric mat is dependent upon the basic process and on variations of application within each process. Some non-woven fabrics do exhibit anisotropy in one direction of the fabric; however, this can be used to advantage when several mats are cross-laid together to provide a fabric of the required thickness. In deed, most non-woven products, except highly calandered, heat-fixed geotextiles, are isotropic in structure and most mechanical characteristics.

The final process in the production of non-woven fabrics is that of bonding the fibres together in some way to produce a stable fibre mat. Three basic bonding methods are generally in use, singly or in combinations.

The fibre mat can be bonded by a mechanical process known as needling or needle-punching. Arrays of barbed needles are punched through the fibre mat and in so doing, mechanically tangle the fibres. This produces a loose fabric 'mat' or 'felt' with a complex and variable pore structure. The mat is usually fairly thick and compressible with relative movement between the fibres which results in a pore structure that can change depending upon the stresses applied to the fabric. Non-woven construction generally does not afford the rapid reaction stress to loading as the structure deforms which the woven products do.

Heat- or melt-bonding is also used. The fabric is subjected to relatively high temperatures and individual filaments weld to each other at their contact points. This method of bonding works well on relatively thin non-wovens and produces a fabric with a simple and discrete pore structure and with little or no flexibility between fibres. The bonding process also results in a loss of fibre strength for those polymers such as polyester and polypropylene which develop their strength through high polymer orientation during the cold drawing process. To some extent this reduction in strength may be avoided by including a polymer in the fibre mat which has a much lower melting temperature and which can then be used as a melt-bonding agent. The bonding polymer can be included in the fibre mat, either as an additional fibre or as the external sheath in the coaxial fibre. Although the production of coaxial filament is relatively expensive, it does have the advantage that for bonding purposes, the number of coaxial filaments in the fibre mat can be closely controlled and with it the number of fibre contacts which become bonds. The proportion of fibre contacts which are bonds can be used to control significantly the mechanical properties of the fabric.

A third bonding technique is to inject the fibre mat with a resin which coats and bonds the fibres together. Resin-bonding improves the structural integrity of the non-woven, increases the abrasion resistance of fibres and environmentally protects the fibres.

2.3 GENERAL FABRIC APPLICATIONS

Geotextiles have been used for a variety of purposes. The majority of uses can be defined by three major functions. Often any single application of fabric uses a combination of these functions but an overview of fabric applications can be gained by looking at each function separately.

2.3.1 Filtration

In the filtration function the fabric permits the flow of ground or surface water without erosion of surficial soils or internal 'piping' of fines within an earth structure.

In conventional cases of one-way water flow, the inclusion of a fabric layer in the body of the soil results in those finest soil particles closest to the fabric being washed against the surface of the fabric or into the fabric pores, and leaving behind a natural filtration layer for further small particles. A continuation of this migration process in the vicinity of the fabric leads to the development of a naturally-graded soil filter adjacent to the fabric. In an undisturbed environment it is this soil filter or filter cake that actually performs the function of filtering and the fabric acts only as a catalyst for the filter cake formation. This filter cake would be expected to have a lower permeability than the geotextile. The interaction of these fines with the fabric will in the long term affect the success of the fabric installation. Improperly matched geotextile opening sizes and adjacent soil sizes result in clogging by fines and thus reduced permeability, resulting in a loss of effectiveness of the installation. Over time, further clogging can occur, not only as a result of a continued (but much slower) movement of soil fines through the filter cake, but also as a result of mechanical interference, biological growth or fabric disintegration. All these aspects can result in a breakdown of the system and subsequent structural failure due to excessive piping or hydrostatic build-up.

Present applications of fabric for filtration purposes include:

- . wrapping a stone, or stone and drain systems in French (Figure 2.1) and Trench (Figure 2.2) drains, to prevent the migration of the surrounding soils into the drainage aggregate
- . wrapping fabric around drain pipes to prevent clogging of the pipe orifices (Figure 2.3)
- . replacing the graded aggregate in base course drains (Figure 2.4), again to prevent the intrusion of the parent or backfill soil into the drainage aggregate
- . use as a structural drain, often in combination with a pipe drain, behind retaining walls (Figure 2.5), to help alleviate hydrostatic and seepage pressures without washing out the fine soil particles

- . use as a protective layer around vertical or horizontal drains in embankment construction (Figure 2.6), again in order to prevent the intrusion of soil fines and to maintain stability through improved drainage.

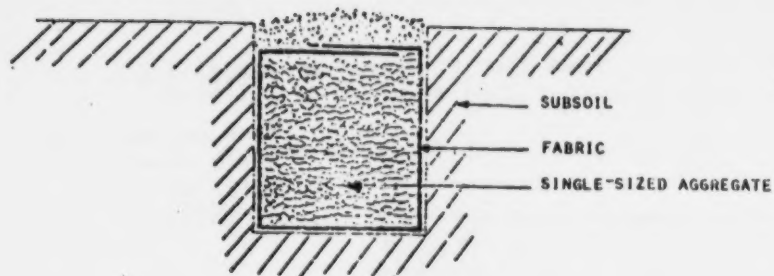
Since the potential for clogging is a significant factor in the use of fabrics for filtration purposes, it seems apparent that fabric selection must be based not only on the characteristics of the fabric but also on the characteristics of the soils in which it is to be placed.

The fabric pore size and pore size distribution will control the maximum size of soil particle that can migrate through the fabric and the flow characteristics (turbulent or laminar) at the soil/fabric interface. The percentage open area of the fabric will control the quantity of soil fines migrating into the fabric and the thickness of the fabric will control the migration of those fines through the fabric and any subsequent clogging.

The grain size distribution will affect the soil's ability to develop a 'filter cake', and with a uniform soil, care must be taken to ensure the fabric pore size is smaller than the predominant soil grain size as with conventional sand filter design.

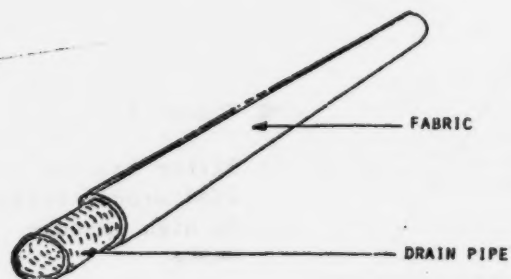
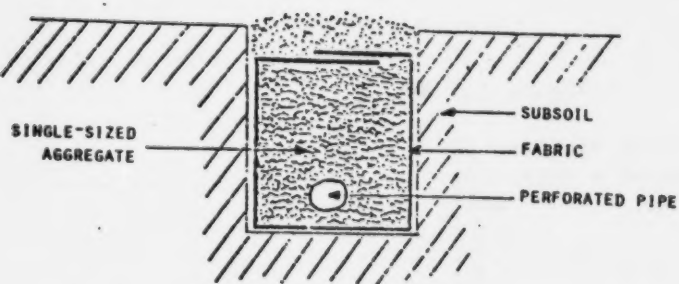
2.3.2 Drainage

When used for drainage, the plane of the fabric (or as simply conceived, the filtration function implies suitable drainage normal to the plane of the geotextile) is intended to supply a drainage path. It should be immediately obvious that in order to do this effectively, the fabric must behave such that flow from the soil into the fabric can continue without clogging occurring. Thus, all the criteria required for filtration must first be met by the fabric in order that it should also effectively carry out its drainage function. The quantity of flow through the plane of the fabric is directly proportional to the thickness of the fabric and the fabric's permeability. A soft or less rigid fabric would be susceptible to compression and would experience a reduction in both thickness and permeability when subjected to compressive loading. Thus fabrics with a stiffer rigidity should be favoured for drainage purposes.

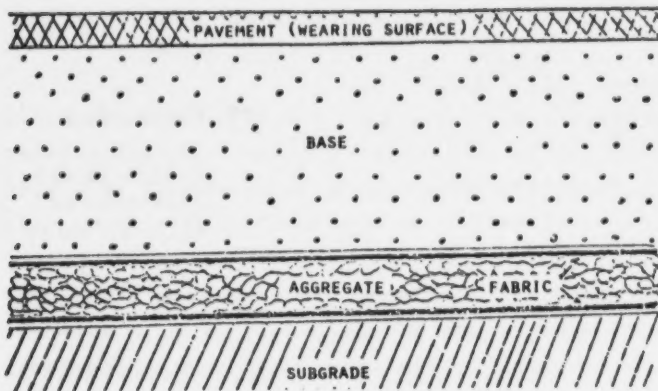


◀ **Figure 2.1**
French drain
constructed
with a fabric

Figure 2.2 ▶
Trench drain
constructed with
a fabric



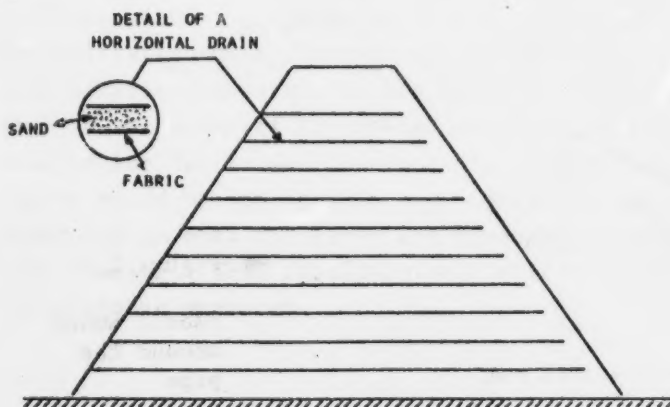
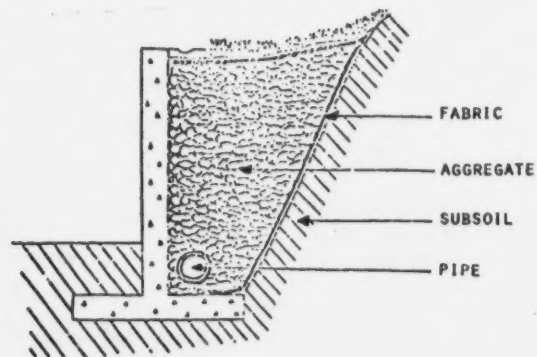
◀ **Figure 2.3**
Fabric wound
around the
pipe



◀ Figure 2.4

Base course
drain constructed
with two layers
of fabric

Figure 2.5 ▶
Drain with fabric
behind a retaining
wall



◀ Figure 2.6

Filter fabrics
used around drain
in high embank-
ments

At present, fabrics have been used to provide drainage paths:

- . behind retaining walls to relieve hydrostatic pressure (Figure 2.7)
- . as vertical drains in soft soils (Figure 2.8) to provide the drainage path and speed consolidation
- . as horizontal drains in embankments (Figure 2.9) to reduce pore water pressures and accelerate consolidation.

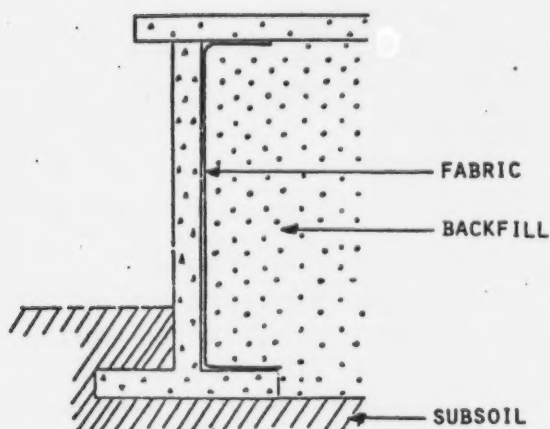
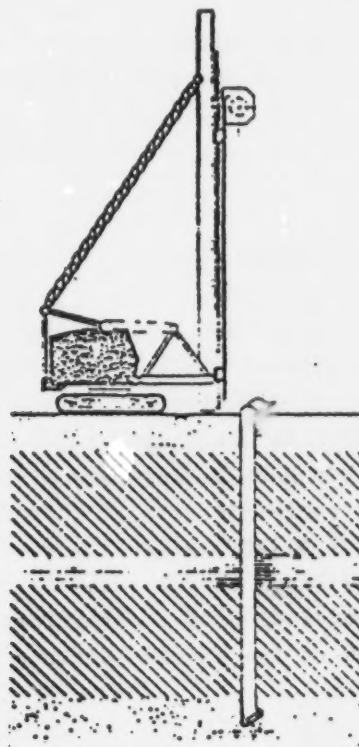


Figure 2.7

Use of fabric for vertical retaining wall

Figure 2.8

Procedure for installation of the vertical fabric strips



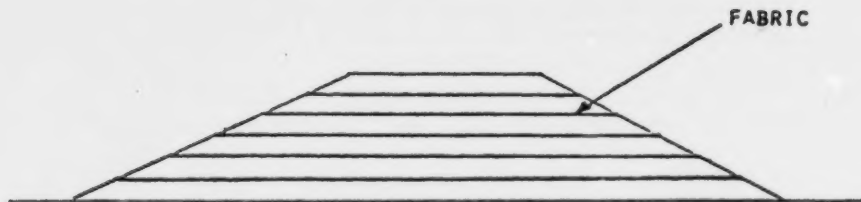


Figure 2.9 Horizontal drains in embankment

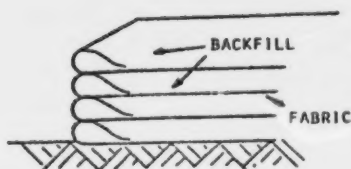
For drainage purposes, the permeability of the fabric both longitudinally and transversely must be assessed, as well as its resistance to clogging. As with all fabric installations, the fabric's environmental durability must also be taken into account.

2.3.3 Reinforcement

When used in a reinforcement function, the fabric installation is intended to provide tensile strength within the fabric-soil system. It is held that earthwork strengths are improved by frictional or adhesive properties with the soil mass. Although substantial work has been applied to the study of these systems, no general theory has been developed which is applicable in all cases.

Fabric reinforcement applications are at present viewed in four general categories.

The first encompasses 'retaining structures' (Figure 2.10). In this case the structure is similar to more conventionally reinforced earth structures and much of the analysis for reinforced earth is applicable to this type of application. Such theories as the 'rigid block theory', the 'equivalent homogeneous soil theory' and the 'failure wedge concept' have been applied. The 'failure wedge concept' has been researched most extensively. The concept is based on conventional lateral earth pressure in which a wedge of soil is considered to be tied back to stable soil by reinforcing geotextile (Figure 2.11). This approach leads to the ready calculation of the required strength and embedment length of the reinforcing with the knowledge of the tensile strength of the fabric in plane strain, and the shearing resistance

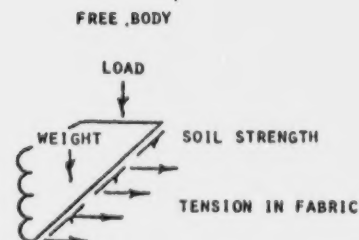
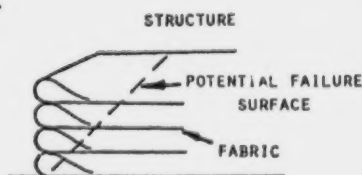


◀ Figure 2.10

Retaining structures
application

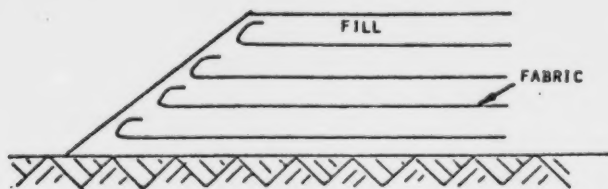
Figure 2.11 ▶

Failure mass concept
of fabric reinforced
soils--retaining
structures



between soil and fabric. Since failure of the system is usually defined in terms of some maximum allowable deformation, the strength of the fabric is also required at the stress equivalent to the deformation of the structure at failure. The creep characteristics of the fabric would also need to be known, either static creep over the long term, or cyclic creep (fatigue), depending upon the type of loading regime anticipated.

A second category, 'reinforced embankments', includes fabric layers in the mass of the embankment to improve its stability (Figure 2.12). The differentiation is made from the first category due to the presence of the embankment side slopes. Although a sliding wedge method (Figure 2.13) can be used to analyze the system in a manner very similar to the failure wedge concept, the approach assumes that both the soil and the reinforcing fabric fully develop their respective strengths. For this to be the case, partial failure of the system may be necessary for this to occur, or alternatively, the 'failure' may be 'forced' during the construction phase by deliberately overloading the system. All the fabric/soil characteristics that require definition for analysis of retaining structures are needed for the analysis of reinforced embankments.

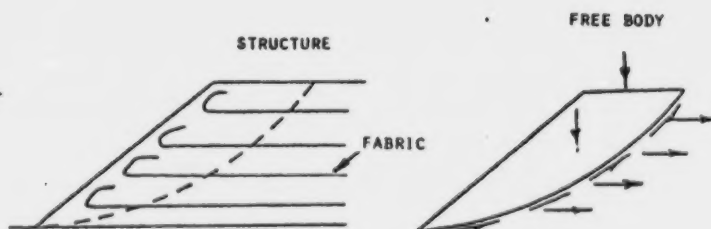


◀ Figure 2.12

Embankment
reinforcement
application

Figure 2.13 ▶

Failure mass concept
of fabric-reinforced
soils--embankments



When fairly low fills are required on very soft foundations, fabrics have been used to provide 'fill' foundation reinforcement. In this case the fabric is used at the fill/foundation interface (Figure 2.14). Although the same fabric/soil characteristics already cited for the reinforcing function are relevant here, no theory is available which adequately describes the system's behaviour, and many modelled attempts to do so have led researchers to conclude that the fabrics did not produce any benefit due to their reinforcing effect, despite field observations which indicate that the use of fabrics can reduce the amount of fill required to provide a stable embankment by as much as a third.

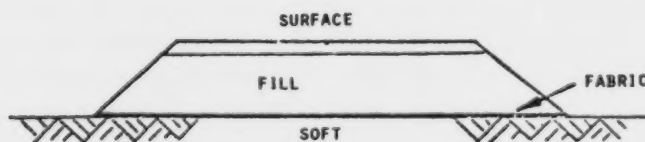


Figure 2.14 Low-fill-on-soft-foundation
reinforcement application

This inconsistency can at present be explained in two ways. Either the fabric function in this case is not reinforcement but separation, or the reinforcement function is not uniform over the entire installation

as most models would assume, but is mobilized only in localized weak spots, thus providing a bridging function and forcing an otherwise heterogeneous foundation soil to behave in a more homogeneous manner. If this is the case, then the design of reinforcement for such cases will be dependent upon past experience, test embankments and trial and error.

The fourth category of reinforcement is 'subgrade stabilization' (Figure 2.15). In many ways this is very similar to fill foundation reinforcement except that the type of failure against which preventative action is being taken is not a massive failure of the system due to failure in shear, but a failure of the running surface due to rutting, under multiple applications of loading. The stresses involved are much smaller. A stress distribution is required which allows the calculation of the effect of the fabric on the subgrade stresses and a correlation is needed between rut depth and the number and magnitude of the stress applications.

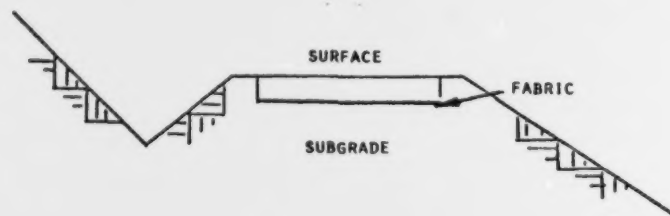
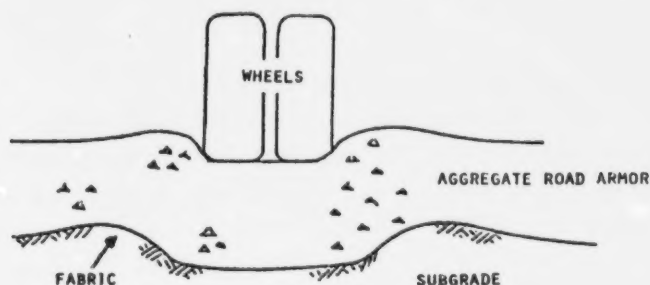


Figure 2.15 Subgrade stabilization application

Tests of specific fabrics have provided some empirical methods of design which are specific to those fabrics and general design charts have resulted.

Once a rut has been developed, tensile stresses are mobilized in the fabric (Figure 2.16). The vertical components of these stresses should then to some extent resist wheel loads (Figure 2.17) and reduce subgrade stress, which in turn should reduce rut development. Thus, fabric properties which would be most applicable to this problem would be creep and stress/recovery behaviour in the particular environment to which the fabric is to be applied. A plane strain tensile test result would give some indication of the appropriate fabric properties, even

though the problem is not truly one of plane strain. However, the total environment -- both loading and application -- must be considered in any attempted analysis.

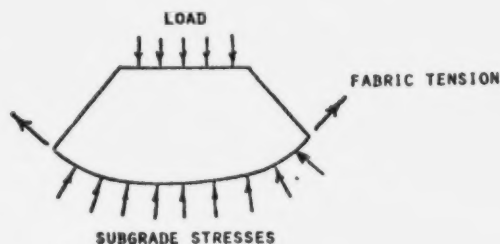


◀ Figure 2.16

Fabric in a rutted roadway section, section through rutted roadway

Figure 2.17 ▶

Fabric in a rutted roadway section, rut section free body indicating major forces



2.3.4 Separation

This fabric use is intended to prevent the physical mixing of two materials, usually the mixing of a fine-grained material into a coarser-grained material where to allow such mixing would result in a loss of stability of the coarse-grained material. Fabric is usually applied for separation purposes when one (or both) of two phenomenon are present: subgrade pumping and intrusion.

The processes involved in subgrade pumping are well known; stresses applied on a base course of a coarse material are transmitted to the subgrade. When this subgrade is of a fine-grained soil with water present, pumping occurs. A soil/water slurry forms at the base

course/subgrade interface and excess pressures force this slurry up into the base course where fine soil particles are deposited, contaminating the coarse granular material of the base course. Quantative evaluations of the process have not proved possible and the stresses necessary to initiate pumping have not been defined, nor has the degree of susceptibility of fine-grained soils. Accepted practice has been that pumping can be prevented by the inclusion of a graded granular filter in the pavement structure adjacent to the subgrade to prevent pumping. The use of fabric is intended to replace this graded granular filter. This use of fabric is of particular application to the railroads and is expanded upon further in Section 2.5.

Intrusion is regarded as a plastic shear flow phenomenon, in which coarse particles are punched into a soft subgrade, which in turn is squeezed into the voids in the aggregate layer. This differs from subgrade pumping in that the subgrade is deforming in a solid (plastic) rather than a liquid state. The relationships between soil strength, loading and soil, and aggregate grading are not known, but many successful fabric applications have shown that fabrics can prevent this type of contamination.

Some aspects of the fabric's behaviour which determine its success in this application can be identified. The fabric's maximum pore size must be such to prevent subgrade plastic flow. This pore size is, however, relatively large. The fabric must also have a high punching strength to prevent intrusion of the base course aggregate through the material, and its bursting strength must also be adequate to prevent failure across voids in the base course.

2.4 TESTING PROCEDURES

Many testing procedures have been adopted or developed for geotextile testing. General approaches are described here, with those tests typically applied (if at all) in North America being specifically cited.

2.4.1 General Properties

Absorption: Several methods are used to measure the fabric's ability to absorb liquids. ASTM (American Society for Testing and Materials) 1117-69 also recommends the use of liquids other than water, such as saline solutions, etc.

Specific Gravity: ASTM D-792 provides a procedure for determining the specific gravity by weighing the test specimen in air and water.

Thickness: The thickness of a fabric is in most tests defined as the distance between pressure plates under a specific pressure. ASTM specifies a range of pressures -- 0.35-700 g/cm² -- depending on the fabric type. However, this test was not specifically designed for measurements with construction fabrics.

Weight: Weight is usually measured for a given unit of area or length. ASTM D-1910 requires the weight in grams/square metre or grams/linear metre, with the width specified. Both length and width are to be measured under a no-tension condition.

Fibre Dimension: Depending on the type of fabric, this can be determined by one of two methods, according to ASTM D-204. Four strands of fibre are placed side by side on an anvil and measured with a thickness gauge, or the thickness is determined optically using a microscope with a movable stage and micrometer settings to measure the movement of the microscope crosshairs. This second method has been adopted for use by the U.S. Army Corps of Engineers.

2.4.2 Mechanical Properties

Burst Resistance: This property is intended to define the fabric's ability to withstand forces applied perpendicular to the plane of the fabric. Several ASTM tests -- D-461, D-231, D-774, and D-751 -- have been devised to determine the bursting strength of different materials under specific conditions of temperature, relative humidity and pressure.

Creep and Stress Relaxation: Creep tests measure either the extension of a fabric under load as a function of time, or the time to rupture

of a specimen under a specified load and conditions. ASTM D-3334 is of the latter type. Stress relaxation is measured as the decrease in tensile stress as a function of time with a given elongation under specified conditions.

Compressibility: This property has been measured by stacking ten discs of the fabric in a test cylinder placed on an oedometric stand to which pressure is applied by the use of a piston.

Cutting Resistance: A test has been developed to measure this function which involves dropping aggregate from a specified height onto the fabric. The fabric is seated on a bed of soil or aggregate.

Fatigue: In general these tests stress the fabric longitudinally at a constant rate of extension to a specified load and then relax it to zero load until the sample fails under fatigue in this case. The equivalent ASTM D-885 does not seem to be entirely appropriate and investigating other tests is recommended.

Friction: The bulk of the tests developed which measure this function also use a given weight or confined volume of soil, and the force required to remove the fabric is determined.

Puncture Resistance: The ASTM D-154-68 test uses a fixed sample which is punctured by a moving needle. The degree of damage is measured.

Stiffness: Two tests - ASTM D-1388-65 and BSI (British Standards Institution) 3356-61 -- use virtually the same method. At a predetermined angle of sag from the horizontal, the length of unsupported specimen is measured.

Tear Resistance: Many types of tests have been developed to measure the force required to tear a pre-cut sample of fabric completely in two. Both dynamic and static tests are available. ASTM D-2261-7 and ASTM D-2262 are static tests, and ASTM D-1424 and ASTM D-2263 are dynamic. The tests differ in the shape and clamping method of the sample and in the propagation method used to initiate tearing.

Stress-Strain Characteristics: Many tests exist which stretch the fabric mechanically until it breaks, and measure both the load and

extension at failure. Among these is ASTM D-1692-64. However, many variations on the basic test are often referred to specifically in the literature; these are described below.

The Strip-Plane-Strain Tensile-Test mechanically extends a strip of fabric until it breaks. It varies from the standard tensile test in that provisions are made to restrain the sample in a direction at right angles to the load application.

The Grab Tensile-Test also mechanically extends the fabric sample until failure, but in this case only a part of the width of the fabric is clamped.

The Modified-Grab Test is, as its name suggests, a modification of the Grab Tensile Test. The modification exists in the preparation of the sample, which is split so that all the yarns bordering the specific portion of sample to be tested are cut. This gives the breaking load to fail a specific width of fabric.

The OSU-Ring Test grips the fabric in a 6" diameter ring and stresses it with a 5" diameter plunger. This test gives the fabric strength in pounds per square inch of fabric and the percentage elongation at failure.

The Biaxial-Tensile-Strength Test clamps the fabric specimen in two directions, pretensions it stepwise in both directions, and then loads the specimen to failure.

The CBR-Method Tensile-Strength Test uses a CBR mould to mount the fabric which is then stressed by a piston. A measuring ring is used to determine the magnitude of the stressing force as it is applied.

2.4.3 Hydraulic Properties

The basic fabric properties which affect the hydraulic behaviour of the fabric are its Equivalent Opening Size (EOS), its pore size distribution, and its porosity.

The EOS is defined as the number of the U.S. standard sieve which has openings closest in size to the geotextile effective openings. To

measure the EOS, a fabric specimen is subjected to sieving with a discrete particle size to test for the size which gives 95 per cent passing after a predetermined vibration period. A quite different test method is used by the BSI to determine the opening sizes in fabrics. Air is forced under pressure through the fabric wetted by a fluid with the top surface of the fabric also covered with the liquid. The pore size is determined by a combination of the pressure required and the surface tension of the liquid.

The pore size distribution curve can be determined in much the same fashion as soil gradation curves, except different particle sizes are used to determine the percentage by weight retained on the fabric after a specified vibration period.

Permeability can be measured with standard water permeability tests, both longitudinally and transversely, depending on the use for which the fabric is being tested. Furthermore, ASTM D-737 measures the rate of air flow through the fabric which is required to maintain a predetermined pressure differential between the two surfaces of the fabric.

Transverse permeability of the fabric is normally tested using a standard falling head -- or constant head -- permeameter. Several variations of these two basic tests are available which differ in the sample size used and the pressure head required.

Clogging and piping resistance is usually measured in the same type of apparatus, except that a soil/fabric system is tested rather than the fabric alone. At the end of the test the amount of soil trapped in the filter is measured. A similar procedure adds the soil or silt directly into the water so that the fabric is tested with a slurry, and this is referred to as a slurry test procedure. It is noteworthy that in situ field performance in railway applications is not well duplicated by such modelling.

The performance of the fabric as an aid to drainage depends on its ability to transmit water in its plane. The few tests developed to assess this quality all attempt to model this process and measure the achieved flow rate under different water pressures.

2.4.4 Durability or Wear

The fabric's ability to perform is dictated by its ability to maintain its original strength in the environment in which it is placed. In most of the tests for durability, the fabric's tensile strength is retested (often as in ASTM D-1682) after being exposed to a change in environment. Both high- and low-temperature exposures, and the effects of a freeze-thaw cycle, can be tested in this way. Similarly, the material's resistance to acid and alkalies can be ascertained by testing the tensile strength after immersion in acid or alkali baths (ASTM D-543-67). The fabric's ability to maintain its integrity under biological attack from soil micro-organisms can be judged by placing it for a predetermined period in conditions under which it will be in service and then retesting its tensile strength. The effects of oxidation (CRD-C-577-60) and the fabric's ultraviolet stability (ASTM D-3334) can be similarly modelled, as can weathering with cycles of water spray (of varying intensities) and light (of various qualities) (ASTM G-33069, D-1436 and D-2565-70).

At present abrasion resistance is measured by abrading the fabric sample in an abrasion machine and then measuring its remaining strength. ASTM D-1175 is an example of this approach. However, the type of abrasive regime to which fabrics are exposed in use has not yet been successfully modelled.

2.5 PRESENT USES OF FABRIC IN TRACK

Railways in North American have looked to the use of 'geotextiles' as a solution to some of the problems encountered in the maintenance of track for only the past five or six years. Many of the early fabric installations were looked upon as 'trial' sections.

Geotextiles are frequently used to control railway track 'pumping'. Some railways are now installing fabrics as a matter of course when renewal work is done on site-specific locations such as grade crossings, switches and crossovers. In this use, the fabric acts as a filter and separator, and provides an improved drainage path within or under the ballast.

Subgrade pumping (and similarly degraded ballast/subballast pumping) occurs when a fine-grained subgrade (often a clayey silt) with excessive moisture is exposed to the dynamic loads resulting from the passage of a train, or in the case of a grade crossing, of both trains and highway vehicles. The loads transmitted to the soft subgrade result in the formation of a soil/water slurry which, forced by subsequent loadings up into the voids of the ballast above, contaminates the track structure, decreasing the permeability, thus compounding the moisture problem, and reducing its shearing resistance. In track, the problem is further compounded when drier conditions prevail. The contaminated ballast is often cemented by the dried fines and performs dynamically as a far stiffer track bed, this in turn increases the magnitude of the dynamic loads due to traffic, and results in the contaminated section degrading under use far more quickly than those sections of track not subject to pumping. The next wet period finds a section of track that is not only susceptible to pumping, but also substantially degraded. The system, once established, is thus prone to progressively increasing damage, irregardless of moisture conditions.

A fabric installation to alleviate these conditions is used as a separator, to physically prevent the ballast being pounded down into the soft subgrade and the subgrade from being squeezed up into the voids of the ballast. Since the pumping itself results in a soil/water slurry, the fabric also acts as a filter, allowing the passage of the water vertically through the fabric into the more freely draining ballast, but preventing the accompanying migration of soil fines. Finally, the fabric itself provides a drainage path within its own thickness.

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Testing Procedures

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ASTM D 737-75, "Standard Test Method for Air Permeability of Textile Fabrics."

ASTM D 1682-64, "Standard Test Methods for Breaking Load and Elongation of Textile Fabrics."

ASTM D 1777-64, "Standard Method for Measuring Thickness of Textile Materials."

ASTM D 2263-68, "Standard Method for Testing Automotive Fabrics."

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CHAPTER 3

THEORETICAL CONSIDERATIONS

3.1 INTRODUCTION

In-track rehabilitation geotextiles are mainly employed as a means of preventing new clean ballast, or old ballast which has been cleaned and returned to track, from being fouled with fines accumulated in the underlying dirty ballast or dirty subballast, or by fouling from the subgrade.

The accumulated fines in the dirty ballast may have come from many sources, including subgrade migration, impermeable fines in the original subballast source, aggregate breakdown of either subballast or ballast, transported fines in flood water, freight car droppings, wind-blown sources, locomotive sand and the like. Geotextiles will not prevent fines from the last three sources from contaminating clean ballast, but are of value where the foreign source has already contaminated the track support structure and action has been taken to prevent or minimize further foreign source contamination.

In the presence of excess water, most contaminating fines below a track, subject to repetitive wheel loads, will migrate upwards through the track structure. The more free water there is, the faster, in general, the upward migration of fines. Thus, drainage improvement (whether the improvement of side-ditch drainage dealing with surface water, the lowering of the ground water to increase the subgrade strength, or drainage of the track area to prevent water seeping into the subgrade bearing area) is always the first and most essential item in any subgrade stabilization work. Geotextiles should never be used as a substitute for good drainage.

Plate 3.1 shows an earth fill 1.5 m (5 ft) thick over a swampy area which has been subjected to heavy construction equipment. Despite the large depth of fill, water may be seen pumping to the surface. Railroad track with marshy subgrades subject to sufficient repetitions of heavy loads may therefore be expected to pump.

Pumping track, if sufficiently severe, can result in excessive maintenance such that the regular work crews cannot maintain normal track standards. Slow-orders then result, so that freight cars negotiate curves at less than balanced speed. This results in excessive loading of the low rail. Plate 3.2 illustrates what happens to the low rail on a curve subject to a slow order because of nearby pumping track. Plate 3.3 illustrates bent rail observed on track having pumping problems. Once water collects around ties, the water has a detrimental effect on the wood. As illustrated in Figure 3.1, saturated wood has half the holding capacity of cured wood. When this occurs, gauge-spreading and problems from lack of spike-holding can be expected to increase. Pumping track not only adds to the problems of track support structure maintenance, but can become excessive to the point that considerable damage is done to the more expensive components of the track such as the rails and ties. Under such circumstances, geotextiles may be of value in reducing costs.

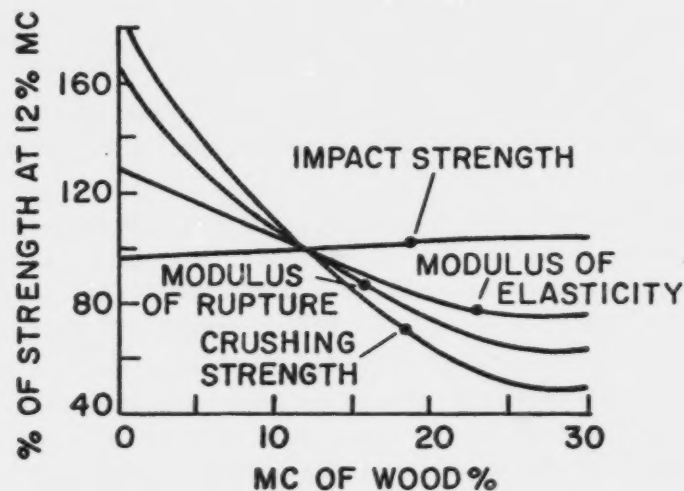


Figure 3.1 Typical effects of moisture on the strength of wood

Geotextiles have found their greatest use in poorly-drained regions of the terrain which are flat and possibly marshy. They are also being used at locations which are difficult to maintain and where the geotextile, by facilitating drainage, will reduce the amount of maintenance required. This is particularly true of such places as grade crossings, diamonds, switches and like track structures.

The main functions of a geotextile in track rehabilitation where the fouled ballast has been sledded, ploughed or undercut is to reinstate the filtering and separating capabilities of the subballast, and the draining capability of the lower elevations of the ballast. These functions are particularly important where the original subballast has been covered with a depth of fouled ballast or is non-existent. The drainage capability of the geotextile, while not obvious initially because of the clean overlying ballast, increases in importance with time, particularly if the geotextile has been properly installed so that it can facilitate drainage away from the track bed under gravitational water pressure. Indeed, even where a subballast exists, the undercutting depth is uncontrollable to the extent that one cannot guarantee that the original subballast interface will be exposed by the undercutter. The drainage function cannot be overemphasized, although, as already stated, geotextiles should not be used as a substitute for good drainage practice.

In general, when dealing with track rehabilitation problems the track has been in existence for some time, and excessive subgrade settlements have ceased. The use of geotextiles for subgrade reinforcement will not, under these circumstances, be a major consideration, but rather they should be highly abrasive-resistant to withstand the harsh environment of ballast particle movement on ballast or subballast aggregate. Indeed, when installed for track rehabilitation, most geotextiles are not tensioned during installation and their ability to reinforce the subgrade without excessive lateral spreading is highly questionable.

From the above, it is apparent that the basic functional requirements of geotextiles in railroad bed rehabilitation technology are definable as:

- (a) Roadbed drainage: to drain water away from the track roadbed, on a long-term basis, both laterally and by gravity, along the plane of the geotextile without buildup of excess hydrostatic pressures.
- (b) Geotextile integrity: to withstand the abrasive forces of moving aggregate caused by the tamping

compaction process during cyclic maintenance, tamping during initial compaction and by the passage of trains on a frequent basis, and to withstand the impact of the ballast drop during placement, along with the long-term environmental effects of chemical weed killers and the like used in track maintenance.

- (c) Filtration: to filter or to hold back soil particles while allowing the passage of water.
- (d) Particle separation: to separate two types of soils of different sizes and gradings which would readily mix under the influence of load and of water migration.

To these may be added the function of soil reinforcement on new construction projects or maintenance where subgrade replacement may occur due to frost susceptibility, and thus the complete track support is reconstructed. For longevity of the undertaking, the reinforcing geotextile (generally a woven type) should be placed at a depth not subject to water pumping from future traffic.

3.3 ENGINEERING PROPERTIES AFFECTING GEOTEXTILE PERFORMANCE

In order to perform functionally, a geotextile used in track rehabilitation should exhibit certain engineering properties which may be measured and used as selection criteria. The most important of these properties are:

- . lateral permeability or hydraulic conductivity
- . pore size between the fibres or equivalent opening size (EOS)
- . ability to resist abrasion
- . ability to resist impact
- . ability to resist chemical environment of a track bed.

Clearly, a geotextile will be subject to tensile forces during installation, which would suggest that tensile strength would be a valuable property. In practice, any geotextile that can meet the requirements

for abrasion and impact should have more than adequate tensile strength. Furthermore, too much emphasis has, in the past, been placed on tensile strength, to the detriment of abrasion and impact resistance. Thus, tensile strength has been deliberately excluded from the above list. On new construction such as a track embankment on weak soil deposits, it will probably be the dominant requirement if geotextiles are considered necessary for reinforcement rather than to reduce pumping.

The ability to conduct water laterally through the geotextile is essential for good long-term performance to reduce pumping, particularly when the ballast immediately above the geotextile begins to be partially fouled. In general, woven and, in particular, monofilament-woven geotextiles do not exhibit the ability to hydraulically conduct water within the thickness of the geotextile. Woven geotextiles, with time, become ineffective and act almost as a plastic sheet to prevent water from draining out of the subgrade. This weakens the subgrade soil, causing it to squeeze laterally from the area beneath the cross-ties and the track to subside. This subsidence may be accompanied by a rise in the shoulder material, further aggravating drainage from the track to the side ditches by causing, with time, water to be trapped in the track area.

The lateral permeability or hydraulic conductivity of unused non-woven geotextiles along the plane of the geotextile may be obtained using the apparatus developed in this project for which a test procedure and associated apparatus is presented, with other test methods, in Appendix A. Typical permeability test results are presented with the field data, where comparisons are made of results of tests on new and field-recovered geotextiles. The coefficient of permeability of a new non-woven geotextile is, in general, close to that of a medium to coarse sand. This is large in comparison with fine sands, silts and clays which constitute problem subgrades due to their inability to drain rapidly and their loss of strength in the presence of excess moisture. Virtually any non-woven geotextile in a clean condition should pass a realistic permeability criterion such as a hydraulic conductivity of at least 25 times that of a problem subgrade. This is the implied criterion of the AREA Manual of Railway Engineering, which requires the d_{15} (sieve size opening which will pass 15 per cent by weight of the soil) of a subballast to be at least five times the d_{15}

of the subgrade, since the hydraulic conductivity of a uniform soil is approximately proportional to the square of its d_{15} value ($k \propto (d_{15})^2$). A major concern of a geotextile installer should be maintenance of this high permeability by prevention of fouling.

The pore size, or equivalent opening size (EOS), of a geotextile is defined as the minimum size of a uniform gradation of spherical particles, generally rounded silica sand or glass beads, which fail to pass through the geotextile. Sand is recommended, since glass beads are more subject to static electricity, resulting in possible error. A test method developed under this project is given in Appendix A and specific results are presented with the field data. The laboratory test consists of continually increasing the uniform particle size of the sand until less than 5 per cent of a minimum weight of 50 grams passes through the geotextile. The d_{85} of the subgrade soil is required by the AREA Manual to be greater than one-fifth the d_{15} of the subballast, the assumption being that the subballast will have maximum void space sizes about one-fifth its d_{15} and thus retain all the particles of the subgrade soil. Thus, logically the EOS, which is a direct measure of the maximum size of the geotextile's continuous voids, should be less than the d_{85} of the subgrade soil. In practice it is found that, except for geotextiles where the fibers are physically bonded (heat- or resin-bonded), the soil particles will push their way into a geotextile, dramatically increasing its in-track EOS. Even heat- or resin-bonded geotextiles have been found to be unable to completely resist particle penetration, as will be presented later in the field evaluation. It is the experience of the writers that geotextiles for track rehabilitation should have an EOS at least as small as the lower limit of fine sand (74 microns or a No. 200 sieve) and preferably an EOS less than the smallest the writers have been able to measure (38 microns or No. 400 sieve). Very simply, if a geotextile is held in front of a bright light, one should not be able to see even the minutest holes through the geotextile.

Geotextiles which do not meet the above criteria of small pore sizes have, as presented in the field-observed data, exhibited several deficiencies with regard to their functional requirements. In geotextiles with relatively large pores, particles of less than the EOS intrude freely, and particles of larger size are forced by the repeated loading of passing axles into the geotextile. Plate 3.4 illustrates

these two points, showing sand size particles retained in an unused geotextile after an EOS test and also in-track fouling of the same geotextile type. These particles cause fouling and thus a reduction in the geotextile's permeability or hydraulic conductivity. The larger the pore size, the larger the particles able to enter, and for any given soil grading, the higher the percentage of the underlying soil that can penetrate and pass through the geotextile, preventing any cake formation and thus the filtering ability of the geotextile. Furthermore, the larger the particle entering the geotextile, the more abrasive that particle is to the internal fibers of the geotextile, facilitating the abrasion and cutting of the fibers of the geotextile, which will eventually prevent it functioning as a separator.

Clearly if particles are being forced into the geotextile, opening up the random fiber structure, any system of fiber-bonding, provided it does not foul the opening size, should be beneficial to the geotextile performance. Such a bonding of fibers is seen in Plate 3.5. On the left are some 6-denier fibers and on the right some 15-denier fibers. It is not surprising then that those geotextiles that had been resin-dipped and forced-air-dried to maintain their porosity and permeability were observed to out-perform, both in the field and the laboratory, geotextiles of similar weight and construction which had no bonding.

The ability of a geotextile to resist abrasion may be tested in the laboratory in accordance with ASTM D1175's "Rotary Platform, Double Head Procedure" using a Taber Abrasor. Once abraded, the sample is assessed for its tensile strength. A grab strength is recommended by ASTM but this tensile test gives only a uni-direction value and geotextiles are subject to bi-directional forces. Accordingly, a method of testing the bi-directional loss of strength and modulus was developed as part of this project and the test technique is described in Appendix A. The developed testing technique may also be used to test geotextiles for their creep characteristics and their resistance to repeated loading. For a quick, crude assessment of resistance to abrasion, the geotextile may be rubbed, with a set number of strokes, using a ballast aggregate particle or between the finger and thumb of one's hand. Even using a crude assessment, it can very quickly be verified that resin- or heat-bonded fabrics are more abrasive-resistant than those without that form of bonding, and that a low density of needle-punching results in less resistance to abrasion than with a high density of needle-punching.

The Rotary Platform Double Head procedure described in ASTM D1175 allows for a choice of abrasion stones and stone weighting. While these may be specified by the user, the usual stones and weights used in other fields of civil engineering are two rubber-based CS-17 Calibrase abrasive wheels loaded with 1000 g (2.2 lb) each. Usually 1000 cycles of the rotary platform is also specified. This rotary process requires 20 to 30 minutes to perform. Unfortunately, 1000-cycles of the CS-17 stone does not simulate the highly-abrasive nature of track. Plate 3.6 illustrates the effect of 10,000 cycles of the CS-17 stone on some different, similar-weight geotextiles. Four of the geotextiles shown have been resin-dipped and the fifth, which was not subject to treatment, has an abraded hole through its thickness. Clearly the use of a test of 200 to 300 minutes duration is not typical. A much coarser stone, such as the H-18 calibrade wheels, is of more practical value for railroad use. Data for a number of geotextiles, including those seen in Plate 3.6 using 1000 cycles of the H-18 stone and then tested in the tensile tester developed in this program, are shown in Figure 3.2. The results show that the H-18 stone is much more practical for testing geotextiles for railroad use than the CS-17 stone.

As an alternative to the Taber Abrasor, a Geotextile-Aggregate Repeated-Loading Abrasion test was developed under this project and the test procedure is given in Appendix A. The main disadvantage of the test is that it requires twenty-four hours for each 100,000 cycles of repeated loading, and thus ten days represents the equivalent of 30 million gross tonnes (33 MMGT) of traffic or one year on a heavy-density railroad.

The ability of a geotextile to resist the impact of falling aggregate during ballast placement may be simply tested by dropping a known weight (5 kg or 11 lb) of ballast a given height (1 m or 40 in.) onto a geotextile placed on a prepared aggregate surface (or where more uniformity is required, a concrete floor or steel surface). The drop can be repeated several times for better assessment between geotextiles, but only those that show negligible or no damage are recommended for use. A standard testing technique developed in this project is given in Appendix A. Again it is the experience of the writers that needle-punched resin-dipped geotextiles perform best.

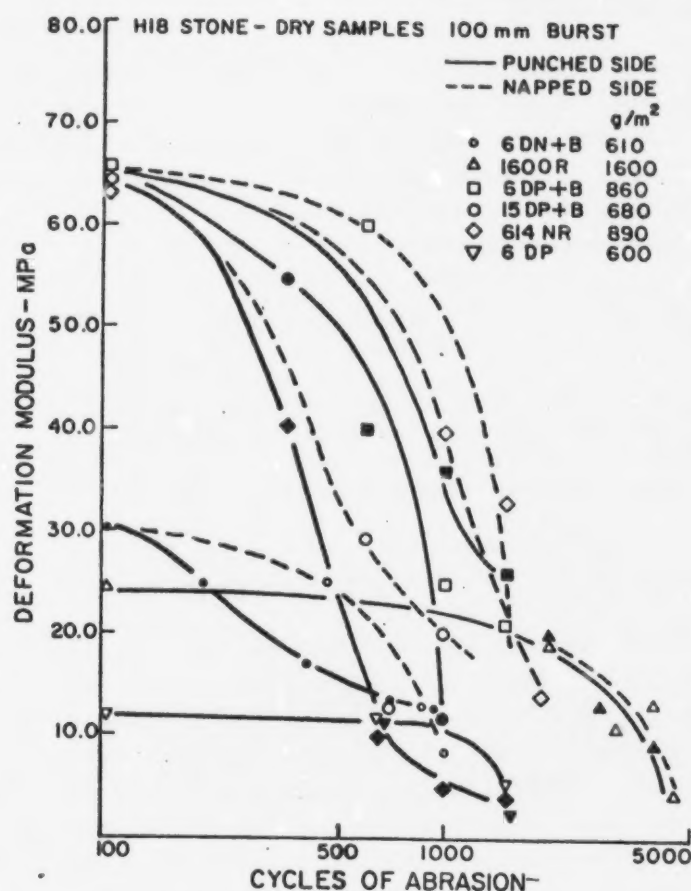


Figure 3.2 Effect of wear on tensile tester modulus

Little is known about the chemical environmental effect on geotextiles in track service, particularly the effect of long-term seepage of fuel oil and herbicides common to most tracks. Resin-dipping may be expected to help to protect fibers from detrimental effects of track pollutants.

A further test developed in this program was the Capillary Rise Test described Appendix A. None of the geotextiles tested showed any extensive rise (more than 300 mm or 1 ft) and therefore the test is given for completeness of the project work. Also, since geotextiles should be laid to drain water under gravity, the test is inapplicable to railroad use.

There are two major divisions of geotextile manufacture: woven and non-woven. Because of the importance of lateral drainage capability of a geotextile for long-term performance, only non-woven types are considered suitable for track rehabilitation. The main non-woven geotextiles in use, and the major finding presented later in field evaluation, may be summarized as:

- . heat- or spun-bonded which, are observed to foul easily on a long-term basis
- . needle-punched without resin-dipping, which have been observed to have low abrasion and impact resistance; abrasion resistance in general increases with increased needle-punching
- . needle-punched, which has been resin-dipped and then forced-air-dried to ensure good porosity.

It might be thought that if resin-bonding was found to be of such value, then calandered (spun and pressed) heat-bonded geotextiles would also perform well. Unfortunately this was not found to be the case. The thin heat-bonded geotextiles were found to foul very easily and became impermeable, exhibiting characteristics similar to woven geotextiles. While no positive explanation for this has been established, it is postulated that the heat treatment causes the pore sizes through the geotextile to be greater than in the lateral direction or along the geotextile. Thus the larger particles, entering with ease vertically, support smaller particles, which reduces the porosity and prevents lateral drainage. In addition, the heat treatment of thin geotextiles flattens the fiber matrix, as seen in Plate 3.7, making the performance much like woven fibers. Thus, with time the geotextile loses its most important long-term requirement, that of lateral hydraulic conductivity.

Some thick geotextiles are given a surface treatment of heat-bonding only. Data with these thicker-surface heat-bonded geotextiles is inadequate to determine whether such a process is advantageous or not, but since the singlemost important conclusion regarding geotextile manufacture would be, in the writers' opinion, that geotextiles for use in abrasive environments should be resin-dipped, surface heat-bonding

of thick geotextiles would seem a potential alternative. There must, of course, be adequate thickness to prevent flattening of the internal fibre matrix.

3.5 POLYMER TYPE

While there are many fibre polymers available, three are commonly used in North America for railroad geotextiles. These are: polypropylene, polyamide or nylon, and polyester. In Europe and Japan, polyethylene is also in common use. The main factor that should be considered in the selection of fibre type is its ability to remain stable under the environment created by railroad operations. Little work appears to have been done on the long-term effect of diesel fuel No. 2 (generally used by locomotives which are notorious for leakage of their fuel) and vegetation control herbicides such as 2-4-D. Unquestionably, the coating a fibre receives from any resin-dipping done to increase its abrasion and impact resistance is beneficial in protecting it from chemical environmental factors as well. Of those geotextiles recovered from in-track use, the evidence obtained from non-resin-coated materials, which was by no means conclusive or extensive, would tend to favour the use of polyester over the other two polymers. No discernable chemical environmental deterioration was observed for any polymers that had been coated through a resin-dipping process.

3.6 FIBRE SIZE OR DENIER

Since fibres cannot be formed with a guaranteed cross-section, the size of a fibre is measured by its weight in grams of a single 9,000 metre continuous long filament known as 'denier'. In order to obtain a small geotextile pore size, or EOS, a low denier fibre is required. On the other hand, the larger the denier of the fibre, the more resistant the fibre will be to abrasion and cutting. The denier of fibre having the best collective behaviour is still unknown. There appears to have been a tendency for the fibre denier of non-woven geotextiles to decrease with time and presumably with observed performance, with 6-denier fibres being the most common in use today (1982). With increased knowledge, it may be possible to make multilayered units using different denier fibres in each unit of the geotextile. Under no circumstances should two unattached layers of geotextile be used adjacent to one another, since this would allow fines to accumulate between the two

geotextiles. On wetting, these fines become very weak. At least one derailment has been related to this condition where a geotextile was laid as a double thickness over a considerable distance.

3.7 GEOTEXTILE DEPTH

One of the contributing factors to a geotextile's performance in-track is the depth at which it is placed below the base of the ties. It is well known that the intensity of pressure generated from a standard wheel load is distributed through the track structure, decreasing with depth. Theories, such as that presented by Raymond (1978), point out that as the depth of ballast increases below the base of each tie, the load is distributed over an increased area and the maximum vertical pressure is decreased. Depending on the abrasive resistance of the geotextile, there ideally should be an optimum depth where the geotextile can be installed during a track upgrading program that will minimize the damaging effects of ballast punctures and abrasion, prolonging the life of the geotextile. From a practical standpoint, abrasion depends on the deformations occurring at the geotextile level, and thus subgrade modulus which is to a large extent controlled by track drainage, since soil behaviour is very much dependent on soil suction and moisture content. For this reason any relationship between geotextile damage and depth is more likely to result from empirical in-track observations. Such data for one geotextile type are presented with the reported field work.

3.8 SUMMARY OF TRACK PROBLEMS

A summary of track-type-related problems associated with track maintenance and appropriate geotextile and soil tests has been tabulated for easy reference in Table 3.1. This is intended as a guide only and variations could readily occur.

3.9 SUMMARY OF ABRASION AND IMPACT TESTS

As a means of assessing the two abrasion tests and the impact test, a number of geotextiles were tested and their performance assessed. At the time of testing, the CS-17 stone was in use with the Taber Abrasor, so that the more recent suggestion of a switch to the H-18 stone has not been assessed beyond the few tests performed and recorded in

TABLE 3.1

PROBLEMS ASSOCIATED WITH GEOTEXTILES FOR TRACK MAINTENANCE

General Solution	Track Problems	Geotextile Tests	Soil Tests	Field Information
Roadbed Drainage	(1)Lateral drainage (2)Clogging of fabric (3)Longevity	Permeability EOS Same as above	Soil & ballast grading Soil Classification	General drainage conditions
Geotextile Integrity	Longevity of maintenance correction	Impact resistance Abrasion resistance Environmental resistance	None	Placement of geotextile in track support
Filtration	(1)Vertical drainage (2)Clogging of fabric (3)Longevity	Permeability EOS Same as above above	Soil & ballast grading Soil Classification	General drainage conditions
Particle Separation	(1)Infiltrating Subgrade (pumping fines) (2)Infiltrating Subballast (mixing fines) (3)Abrasion, puncturing, or rupture of fabric (4)Longevity	EOS EOS Tensile Abrasion Impact Same as (3) plus chemical and environmental	Soil & ballast grading Soil & ballast classification Semi-qualitative X-ray analysis Off-track subgrade analysis	Reason for geotextile installation Track maintenance history Volume and type of traffic General site conditions
Soil Reinforcement	(1)Failure of soft deposits during construction (2)Lateral movement at soil-geotextile interface during construction	Tensile rupture Grab strength Visual inspection	Instrument for track settlement compaction Profile movement of soil	Secondary importance for undercutting operation Visual inspection

Figure 3.2. In the summary of the comparison, the Taber Abrasor was used with the CS-17 stone, 1000 gram weights and 1000 cycles. The comparison was a visual one, done under a microscope. As such, the comparison is qualitative rather than quantitative, which was the reason for the recent switch to the H-18 stone and the presentation of data in the form shown in Figure 3.2. The qualitative comparison of the performance of a number of geotextiles tested under the procedures used in this project have been summarized in Table 3.2 and some pertinent comments made below.

Woven: The woven geotextiles were found to wear-abrade by the process of peeling when subjected to the Rotary Abrasion Test. The amount of abrasion after 1000 cycles was approximately equal for all four woven samples.

After undergoing ten ballast drops of the Ballast Impact Test, the woven geotextiles frequently showed evidence of peeling, splitting, and being cut. A minor amount of slippage of the filaments was also noted. Geotextile B proved to be the most resistant to impact abrasion, while Geotextile D was the least resistant, the multifilaments having been cut all the way through. Geotextiles A and C were abraded to approximately the same degree and to an extent between Geotextiles B and D.

The most frequent processes involved with wear abrasion of woven geotextiles by the Repeated Loading Test were peeling, splitting, and being cut. Slipping and flattening of the filaments occurred on two of the samples. Three of the woven geotextile samples were punctured after 100,000 cycles of loading. Geotextile B was not punctured and sustained less abrasion than the other three.

Non-woven: Of the non-woven geotextiles having undergone the Rotary Abrasion Test, the most frequent processes of wear abrasion were peeling and alignment of filaments. Geotextile H was cut and punctured after 1000 cycles. Geotextiles I and K showed evidence of major peeling, while the remaining samples showed only minor amounts of wear abrasion.

The common impact abrasion processes seen after ten ballast drops of the Ballast Impact Test were peeling and being cut. Less frequently

TABLE 3.2(a)

EVALUATION OF GEOTEXTILE PERFORMANCE IN LABORATORY TESTING

Properties of Textiles				Test Results		
Geo-textile	Description	Mass (g/m ²)	Thickness (mm)	Rotary Abrasion Test (1000 cycles)	Ballast Impact Test (10 drops)	Repeated Loading Test (ballast-) (geotextile-) (ballast) (100K cycles) (except) (where noted)
A	Woven, polypropylene, flat monofilaments, black (MIRAFI 600X)	203	0.7	Pe ₁	Pe ₂ , Sp ₁ , Cu ₁	Pe ₁ , Sp ₁ , Cu ₂ , Pu ₂
B	Woven, polypropylene, flat multifilaments, black (NICOLON 35)	730	2.3	Pe ₁	Pe ₁	Pe ₂ , Cu ₂
C	Woven, polypropylene, flat monofilaments woven with round monofilaments, black (GEOLON 400S)	271	0.5	Pe ₁ , Fl ₁	Pe ₂ , Sp ₁ , Cu ₂ , Sl ₁	Pe ₁ , Fl ₁ , Cu ₂ , Pu ₂
D	Woven, rounded polyethylene monofilaments woven with flat polypropylene multifilaments, black (NICOLON 70)	250	0.6	rounded Pe ₂	Pe ₁ , Sl ₁ , Cu ₂ , Pu ₂	Pe ₁ , Sl ₁ , Cu ₂ , Pu ₂
				flat Fe ₁	Pe ₁ , Cu ₂ , Pu ₂	Pe ₁ , Cu ₂ , Pu ₂
E	Non-woven, needle-punched polyester mat with polypropylene scrim, fibre length perpendicular to plane of fabric, white (TERRAFIX 370RS)	475	4.0	Al ₁ , Se ₁ , Pe ₁	Se ₁	Pe ₁ , Fl ₁ , Cl ₁ , Cu ₁ (10K cycles)
F	Non-woven, continuous-spun bonded polypropylene monofilaments, heat set finish grey (TYPAR 3601)	203	0.6	Pe ₁ , Cu ₂	Pe ₁ , Cu ₁	Pe ₁ , Fl ₁ , Cl ₁ , Cu ₂ , Pu ₁
G	Non-woven, continuous needle-punched polyester monofilaments, Grey (BIDIM C-28)	198	1.0	Pe ₁	Pe ₁ , Fl ₁ , Cu ₂ , Pu ₁	Pe ₁ , Fl ₁ , Cl ₁ , Cu ₂ , Pu ₁
H	Non-woven, continuous spun bonded polypropylene monofilaments encased in nylon sheath and heat-bonded, white (MIRAFI 140S)	137	0.8	Pe ₁ , Cu ₂ , Pu ₂	Pe ₁ , Fl ₁ , Cu ₂	Pe ₁ , Fl ₂ , Fu ₁ , Cu ₂ , Pu ₂

TABLE 3.2(a) (Cont'd)

Properties of Textiles				Test Results		
Geo-textile	Description	Mass (g/m ²)	Thickness (mm)	Rotary Abrasion Test (1000 cycles)	Ballast Impact Test (10 drops)	Repeated Loading Test (ballast-) (geotextile-) (ballast) (100K cycles) (except) (where noted)
I	Non-woven, continuous needle-punched, double-bonded polyester monofilaments, partially resin-treated, blue and white (TRUE TEX VT 5000)	455	3.3	A ₁ , Pe ₂	Pe ₁	Pe ₁ , Fl ₁ , Fu ₁ , Cu ₂ , Pu ₂ (10K cycles)
J	Non-woven, continuous needle-punched, polyester monofilaments, grey (BIDIM C-38)	415	2.9	Al ₁ , Pe ₁	Pe ₁	Pe ₁ , Fl ₁ , Fu ₁ , Cu ₂ , Pu ₁
K	Non-woven, continuous needle-punched, nylon with polypropylene scrim, resin-dipped, black (TERRAFIX 400NR)	550	4.5	Al ₁ , Pe ₂	Pe ₁ , Fl ₁ , Fu ₁	Pe ₁ , Fl ₁ , Cl ₁

Subscript 1: minor amount of abrasion

Subscript 2: major amount of abrasion

TABLE 3.2(b)

DESCRIPTION OF ABRASION PROCESSES

Process	Symbol	Description
Aligned	Al	Previously non-aligned filaments become somewhat <u>aligned</u> in a preferred direction. Limited to non-woven geotextiles.
Clumped	Cl	Individual filaments form a clump. Limited to non-woven geotextiles.
Cut	Cu	Individual filaments are first cracked and then <u>cut</u> in the transverse direction of the filament.
Flattened	Fl	The thickness of the individual filaments is reduced while the width is increased to produce <u>flattening</u> .
Fused	Fu	Individual filaments are <u>fused</u> together; usually accompanied by flattening.
Peeled	Pe	Small slivers of individual filaments are partially or totally <u>peeled</u> from parent material.
Punctured	Pu	Individual filaments are abraded by various processes and the geotextile develops a hole, thus becomes <u>punctured</u> .
Separated	Se	Individual filaments become <u>separated</u> . Limited to non-woven geotextiles.
Slipped	Sl	Individual filaments of the warp or weft <u>slip</u> along the other and move either closer together or further apart. Limited to woven geotextiles.
Split	Sp	Individual filaments are first cracked and then <u>split</u> in the longitudinal direction of the filament.

the filaments were flattened and fused. Geotextiles G and H were found to abrade the most, and Geotextile G was the only sample punctured by this test. The remaining five samples showed approximately the same amount of impact abrasion.

Peeling, flattening, clumping and being cut were the most common abrasion processes noticed after the Repeated Loading Test. Fusing occurred in three of the seven samples. Geotextile H was the least resistant to wear abrasion. Geotextile I was punctured after only 10,000 cycles. Geotextiles F and G were in the mid-range of wear resistance. Geotextile J was slightly more resistant than Geotextile G. Geotextiles E and K showed the least abrasion and were the only two which were not punctured. (The test on Geotextile E was only taken to 10,000 cycles before a failure in the apparatus stopped the test.)

Woven versus Non-woven: Some general comments can be made with regard to the abrasion resistance of woven versus non-woven geotextiles by these three tests. In the Ballast Impact Test, the non-woven geotextiles appeared much more resistant to impact than the woven materials. The Repeated Loading Test was found to give the most consistent amount of abrasion to both types of materials. Both woven and non-woven geotextiles were found to abrade about the same amount, albeit by slightly different processes.

The rotary (Taber Abrasor) process, ASTM D1175, was found to wear-abrade the woven geotextiles and the resin-dipped non-woven geotextiles (Geotextiles I and K) well, but in a fashion foreign to geotextiles in a railbed. When the Rotary Abrasion Test was applied to the other non-resin-dipped, non-woven geotextiles, the filaments tended to be pushed out of the way of the abrading wheels rather than undergoing abrasion. In many instances, the abrading wheels became clogged with the polymer of the geotextile being abraded after more than 1000 cycles. For these reasons, no comparisons could be made between the woven and non-woven geotextiles for this test procedure using the test technique associated with the Rotary Abrasion Test. It is, however, evident that resin-dipping increases considerably the resistance of non-woven geotextiles to this form of abrasion.



Plate 3.1 Pumping of fill 1.5 m (5 ft) thick placed over swamp subgrade



Plate 3.2 Plastic flow on low rail from slow order imposed due to pumping track



Plate 3.3 Bent rail resulting from pumping at joints

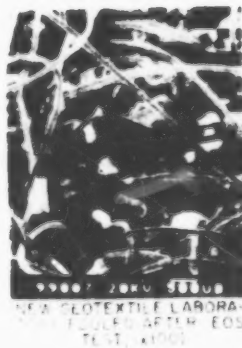


Plate 3.4 Laboratory-fouled new geotextile (left) and same brand track-fouled (right)



Plate 3.5 Typical microscopic view of resin-dipped geotextile showing 6 denier fibre (left), 15 denier fibre (right)



Plate 3.6 Results of Taber Abrador using 10,000 cycles of CS-17 stone with 1000 g weights



Plate 3.7 Typical microscopic view of heat-bonded geotextile showing flattened condition of fibre matrix



CHAPTER 4

PRELIMINARY INVESTIGATION PROGRAM

4.1 INTRODUCTION

The site investigation program evolved from a necessity to uncover the problems associated with track maintenance which could be improved through the use of geotextiles, and to assess the performance of the geotextiles in-track. The first stage of the field program involved the organization of preliminary site investigations where geotextiles had been installed in-track, preliminary assessment of the field conditions at each site, surficial assessment of the geotextile's performance, and recommendations for conducting detailed investigations at a number of selected sites. Conclusions of the study could then be based on field information and laboratory results of the detailed site visits which involved the pulling of a tie at each location and excavating to recover geotextile samples and to assess subgrade, subballast and ballast performance.

4.2 PRELIMINARY SITE INVESTIGATIONS

Preliminary work entailed the establishment of work files according to geographic regions, based on listings of geotextile installations supplied by CN. The initial data detailed the approximate milepost location, type and size of geotextile, year of installation, estimated annual tonnage, plus ancillary information as applicable. Review of the sites according to their geographic location indicated a preference for a given type of geotextile within each region, but this preference varied from region to region.

A tentative list of sites was selected, based on the type of geotextile installed, ease of accessibility, and geographical location. The primary objective was to review as many preliminary sites as reasonably possible, while considering the variety of geotextiles installed. In this way, a broad base of sites was available for a more complete assessment. A list of sites where geotextiles have been installed in-track and from which the final selection of preliminary site visits was made is shown in Table 4.1.

TABLE 4.1

PRELIMINARY LIST OF GEOTEXTILE SITE INSTALLATIONS

Subdivision	Mile	Use	Fabric	Soil Conditions	Drainage
Napadogan (A)	9.6	grx	300NA	clayey silt	Poor, history of pumping at crossings and in embankment
Napadogan (A)	14.9	grx	300NA (500g/m ²)	clayey silt	
Napadogan (A)	200.0	trk	300NA	silty sand? river deposit	Fair, soft subgrade on flood plain, 2 m high embankment
Napadogan (A)	203.20	grx	300NA	silty sand? river deposit	Fair to good (with siding)
Napadogan (A)	204.78	grx	300NA	silty sand?	Fair to good
Rouses P. (L)	6.24	grx	T7616 (520g/m ²)	loam to clay loam till lacustrine deposit	Unknown
Massena (L)	52.13	grx	T7616	silty clay	Poor to fair, sub-drains in track
Alexandria (L)	22.29	grx	C-34 (270g/m ²)	Eamer Loam, med.-textured till underlain by a varved clay	Good, sub-drains in track embankment, subgrade poor
Alexandria (L)	58.70	grx	C-34	Upland sand, loose fine sand with mottled sandy soils	Good, sub-drains in track, poor embankment drainage
Alexandria (L)	65.93	grx	C-34	Bearbrook clay patches of sandy soils	Poor, sub-drains in track embankment
Alexandria (L)	67.44	grx	C-34	between Upland sand and Bearbrook clay	Poor to good (with siding)
Alexandria (L)	68.94	grx	C-34	Bearbrook clay	Poor, sub-drains in track
Dundas (G)	73.97	grx	300N (500g/m ²)	London loam over mottled stoney and clay loam	Poor to good flat ground, poor ditching, double track
Kingston (G)	218.18	grx	300N	Sidney clay overlain by silty sand	Poor to fair, double track
Kingston (G)	219.0	swi	C-38 (340g/m ²)	Solmesville clay loam	Imperfect triple track, 3 m embankment.
Kingston (G)	221.34	grx	C-38	Elmbrook clay till	Imperfect double track, cut section
Oakville (G)	21.96	grx	T100M	Queenston shale	Poor, double track, track subsidence
Oakville (G)	24.42	grx	T100M	Queenston shale	Poor, double track with two spurs, track subsidence

TABLE 4.1 (Cont'd)

Subdivision	Mile	Use	Fabric	Soil Conditions	Drainage
Clearwater(M)	0.5	trk	unknown	"area of soft, boggy ground"	Poor
Wainwright(M)	1.1 254.8	swi	T7607 (240g/m2)	predominantly sandy loam with some fine to med.-course sand	Fair to good, rolling plain, 41 switches
Watrous (M)	246.2	swi	T7607	sandy loam	Fair to good
Watrous (M)	247.1	cro	T7607	sandy loam	Fair to good
Edson (M)	not enough information		TS300	"laid on muskeg under subgrade"	Poor
Fraser (M)	108	sid	T7607	"laid on muskeg under subgrade"	Poor, (siding extension)

Background information was assembled for each site prior to the site visit. This data included soil conditions, surficial geology and weather records for the area. Topographical maps proved to be quite useful in locating the site and identifying the ground features. Air photos would have been useful for the preliminary work but were unavailable on such short notice. Recorded in Table 4.1, for each site selected for preliminary analysis, is an appropriate description of the mapped subgrade and reference to its draining ability.

The majority of the geotextile installations were at highway grade crossings which were easily identifiable from the milepost data supplied with the original information and were easily accessible. Each preliminary site visit included:

- . photographing site conditions
- . noting track and drainage conditions
- . identifying any problem areas evident on the track surface
- . sampling, if appropriate, subgrade materials close to the property line, well clear of track contamination

- . sampling, if appropriate, surficial ballast for aggregate identification.

In all cases, the photographic records proved invaluable for later review and comparison of site conditions. A complete record of preliminary site visits is detailed in Appendix B of this report.

4.3 PRELIMINARY ASSESSMENT

Once the preliminary site visits were completed, an initial assessment of the value of geotextiles to improve track performance could be formulated.

There were sixteen sites visited between June 7 and July 17, 1981 (excluding the two detailed site visits on Conrail track in Ohio during May 19-21, and October 6-7, 1981, which are presented in later chapters). Of those sixteen, visual examination of the track clear of the geotextile installation indicated that there were poor drainage conditions at all but one of the sites prior to installing the geotextile. All were located in areas susceptible to pumping fines and/or subgrade mixing.

Surficial examination of all the Canadian geotextile installations indicated that fifty per cent of the sites exhibited reasonably stable track structure conditions. The balance of the sites may be characterized as medium-weight (about 350 g/m² or 10 oz/yd²) geotextile installations, of which half were nearing a completely fouled condition after only one year in service (12.0 million gross tonnes per year or 13.2 MMGT); and half were completely fouled due to either inadequate geotextile performance or insufficient drainage measures. A summary of the preliminary assessment of the sites is shown in Table 4.2.

Due to the program's deadline requirements, site selection for detailed analysis was based on selecting geotextiles which appeared to be giving a positive performance. Six of the sites received either Terrafix 300N or Terrafix 300NA, which have similar weights with slight variations in structure. This geotextile type had been installed between three and five years prior to the time of the site visits and had been subject to a yearly tonnage which varied between 12.3 and 15.7 million gross tonnes (13.5-17.2 MMGT).

TABLE 4.2

ASSESSMENT OF THE PRELIMINARY SITE INVESTIGATIONS

Type of Fabric	Subdivision Location	Mile-post	Site	Track Conditions		Fabric Performance	Additional Measures
				Before	After		
Texel							
100M	Oakville	21.96	Kerr St.	poor	poor	poor	none
100M	Oakville	24.42	Third Line	poor	poor	poor	shallow ditches
7616	Massena	52.13	Ormstown	fair	good	good	none
Bidim							
C-34	Alexandria	22.29	Alexandria	poor	fair	fair	subsurface drainage
C-34	Alexandria	58.70	Vars	poor	poor	poor	subsurface drainage
C-34	Alexandria	65.93	Carlsbad Springs #1	poor	fair	fair	subsurface drainage
C-34	Alexandria	67.44	Carlsbad Springs #2	poor	poor	fair	drainage
C-34	Alexandria	68.94	Carlsbad Springs #3	poor	fair	fair	subsurface drainage
C-38	Kingston	219.0	East Switch	poor	good	fair	none
C-38	Kingston	221.34	Geddes St.	poor	good	fair	ditching
Terraifix							
300N	Dundas	73.97	Clarke Side Road	poor	good	fair	none
300N	Kingston	218.18	Elmwood Dr.	poor	good	good	shallow ditches
300NA	Napadogan	200.0	East of Quisibis	poor	fair	good	ditching
300NA	Napadogan	203.20	Quisibis Side Road	poor	good	good	ditching
300NA	Napadogan	204.78	Quisibis Side Road	poor	good	good	ditching
300NA	Napadogan	9.6	West of Pacific Jct	poor	good	good	ditching

Track Conditions:

- good - ballast is relatively clean, sufficient drainage, ties are well supported, minimal movement under load
- fair - ballast beginning to foul, wide shoulders and shallow ditches, some tie movement
- poor - pumping fines at surface, standing water, no ditches, excess sleeper movement or wear, track out of gauge

Fabric Performance:

- good - clean, dry ballast, aided by proper ditching and subsurface drains, satisfies long-term maintenance
- fair - providing reasonable filtration and particle separation in the short term, requires additional drainage measures for long-term efficiency
- poor - inadequate geotextile, insufficient drainage measures, reassess the installation, track upgrading required

Time limitations did not permit detailed analysis of the other sites. Five of these, in the Alexandria-Ottawa area on the Alexandria Subdivision, were installed with Bidim C-34 during 1980. Their similar subgrade conditions and similar loading environment would provide a good comparison had they shown good performance. The fact that they had not performed well tended to confirm the poor abrasion resistance of these geotextiles observed in the laboratory test program and at Conrail's Ohio sites reported in later chapters. Four of the five sites received additional drainage assistance from under the crossing and out to the shoulder ditches by buried perforated conduit pipes.

Several sites at Belleville on the Kingston Subdivision and two at Oakville on the Oakville Subdivision were inspected because their close proximity to Kingston allowed a rapid increase to the data base for future reference. The track subsidence reported in Appendix B for the Oakville sites is noteworthy as it is similar to the performance of similar woven-type geotextiles installed on Conrail's Loudonville site as reported later.

4.4 DETAILED SITE INVESTIGATIONS

A more detailed site investigation program would now be effectively organized utilizing those sites where the geotextile appeared to be performing satisfactorily. The program requirements involved returning to the selected sites to establish the track support behaviour to a depth of about 900 mm (3 ft) depth, and ultimately quantitatively evaluating the performance of the geotextile. Two basic criteria were applied to the site selection. These were:

- . selecting sites with similar geotextiles in-track but with different loading conditions
- . comparing a variety of geotextiles under similar loading conditions.

By assessing the data obtained from these sources, reasonable conclusions about the performance of various geotextiles in track rehabilitation could be drawn.

The detailed site investigations included:

- . locating the extent of the geotextile in-track
- . pulling a tie at a suitable location
- . removing the ballast to the geotextile level
- . cutting a swath of the geotextile for laboratory testing
- . continuing the excavation to the subgrade level if appropriate
- . obtaining appropriate ballast, subballast and subgrade samples for laboratory testing
- . photographic documentation.

It was believed essential that a profile of soil conditions below the geotextile be established to document soil behaviour within the total soil support structure. The profile depth thus may vary due to individual site conditions, but where possible or appropriate, it included the original subgrade.

The soil sampling procedure at each site involved taking bulk samples below the rail seat at the base of the tie, just above the geotextile, just below the geotextile, and of each appreciable change in soil type below the geotextile. The samples were sealed in plastic-lined sacks and transported to the laboratory for detailed analysis. Where excessive moisture was encountered during the investigation, the depth and extent were recorded. On reflection, similar samples should have also been obtained on the centreline of the track, since fouling was less evident there than below the rail seat. This situation is not likely to occur from surface fouling which would tend to be uniform across the track. This, unfortunately, was not done but should be done for any future work.

Where possible, an excavation into track without a geotextile, rehabilitated at the same time as the track with geotextile, was obtained to provide comparative data. Ideally the location of these latter excavations would be in track of similar drainage and subgrade conditions which had received the same type of upgrading at the same time as the location with installed geotextile. These locations would act as control sites for each investigation.

Laboratory analyses of the soil samples included, as appropriate, visual inspection and identification, moisture content, sieve and hydrometer analyses, plastic and liquid limits and ballast hardness, and abrasion tests. The geotextile samples were visually inspected and documented on film. A specimen of each was tested for lateral permeability in its dirty field state, then washed in an ultrasonic bath to remove the fines trapped within the geotextile sample and re-tested for lateral permeability in its cleaned condition. A new specimen of a like geotextile was also tested to give a comparison of new and used permeability values. The fine-grained soil samples that were obtained from within the geotextiles were analyzed for particle size distribution. The scanning electron microscope was utilized to qualitatively assess the clogging and internal wear of selected geotextile samples.

CHAPTER 5

ASSESSMENTS OF CN SITES

5.1 INTRODUCTION

Based on the information obtained from preliminary site investigations, six locations on CN track where resin-dipped, 450 to 510 g/m² (13 to 15 oz/yd²) geotextiles were installed were selected for further investigation. The geotextiles at these six sites had the same product design but different codes to identify their source of manufacture. An assessment of individual site conditions and overall geotextile/rehabilitation performance is presented in this chapter.

Laboratory research demonstrated that resin-dipped geotextiles have a greater resistance to abrasion of their fibres than non-resin-dipped geotextiles. The resin-dipping provides an acrylic coating which helps bond the fibres together and must be initially abraded from the fibre before severe mechanical degradation can occur. For geotextile applications in highly-abrasive environments, the extra cost associated with resin-dipping the fibres should be offset by the extended service life of the geotextiles. Thus, first priority was given to investigating 450 to 510 g/m² (13 to 15 oz/yd²) resin-dipped geotextiles of similar manufacture under different installation or track conditions. Furthermore, these geotextiles were the heaviest-weight geotextiles used by CN. If they could not survive the abrasive environment below the rail seat, then in all probability lighter-weight geotextiles would have little long-term impact on track rehabilitation.

5.2 SITES INVESTIGATED

5.2.1 Dundas Subdivision, MP 73.97, Clarke Side Road, London

Preliminary assessment of track conditions at the Clarke Side Road grade-crossing suggests that inadequate surface drainage is the main reason for track instability problems. The flat topography at the site has limited the use of proper ditching at the shoulders and local

grade-crossing height restrictions have prevented raising of the track structure.

It is understood that the geotextile was installed in the north track to help reduce the amount of mixing between the ballast and the underlying soil. Up until the installation in 1976, the crossing required maintenance every six months to ensure good profile and alignment. After the geotextile had been installed, the track maintained good alignment until 1980, at which time the crossing was upgraded again. The geotextile did not correct the problem at the crossing, but it did increase the maintenance cycle from six months to four years. Significantly, track maintenance personnel reported less tie maintenance above the geotextile-installed area than where no geotextile was installed.

The installation procedure was reported to include the removal of the jointed rails and ties at the crossing and excavation of the dirty ballast with a front-end loader. The geotextile was installed at approximately 150 mm (6 in.) below the base of the ties, which suggests that an excavation having a minimum depth of 350 mm (14 in.) was dug to install the geotextile, upon which was placed a uniform ballast. The tops of the ties were at approximately the same elevation as the surrounding ground surface. No improvement was made to the poor drainage conditions which allowed surface water at or near the ground surface to drain into the open track structure, to the detriment of the subgrade soil.

The field visit to Clarke Side Road took place on September 18, 1981. The weather was cool and slightly overcast, with showers the night before. The investigation required establishing two site profiles, one where a geotextile had been installed in-track and the other where no geotextile had been installed in-track. These tie locations are shown on a site plan in Figure 5.1 which shows the ties; Plate 5.1 is a photograph showing the two ties removed from the track. Both locations were reported as being upgraded at the same time. The two soil profiles below the ties should therefore serve as a useful comparison of the effects of placing a geotextile in-track. The soil stratigraphy for both locations, with and without geotextile, are shown in Figures 5.2 and 5.3, and in Plates 5.2 and 5.3, respectively. The grading

curves for the soil samples taken from below the rail seats at both locations are shown in Figures 5.4 and 5.5 for the site, with and without geotextile, respectively. These figures show not only the complete grain size distribution, but also the material passing the 2 mm sieve (No 10) sized downwards from the 100 per cent passing limit (i.e. a grading curve based only on this fraction).

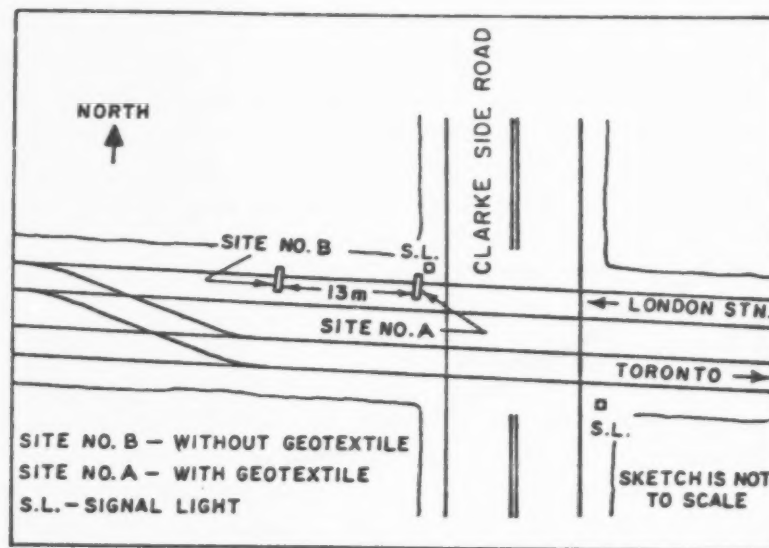


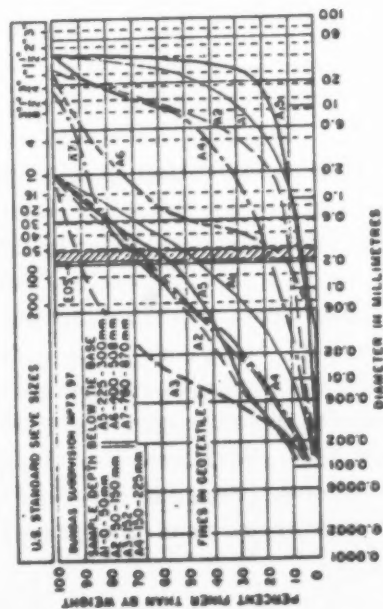
Figure 5.1 Site plan of Clarke Side Road grade crossing (Dundas Subdivision MP 73.97)

The stratigraphy at site A with geotextile had only 50 mm (2 in.) of dark slag ballast directly below the ties. At the track centreline a 25 mm (1 in.) gap existed below the ties (i.e. end bound). The ballast was moist on the surface directly below the ties and quite dense. The ballast was underlain by 100 mm (4 in.) of light brown sand and gravel. The geotextile had been installed beneath this layer of sand and gravel. Another 75 mm (3 in.) of dense brown sand and gravel lay beneath the geotextile. At about 225 mm (9 in.), the soil changed to a dirty greyish-black cemented aggregate with sharp, coarse, gravel-size aggregate throughout. This highly-cemented ballast was about 225 mm (9 in.) thick and underlain by about 250 mm (10 in.) of dense black cinders. Beneath the degraded cinders was about 150 mm (6 in.) of very dense brown sand and gravel, followed by the very dense light-brown

DEPTH BELOW TIE (cm)	SAMPLE DEPTH	SOIL DESCRIPTION	COMMENTS
0			
50	B81	dark grey-black slag ballast	25 mm gap below tie at the centreline of track
130	B82	brown sandy gravel	very dense, moist ballast above and below geotextile.
	B83	terrazin 3008	geotextile was badly damaged from previous maintenance in 1980
225	B84	brown sandy gravel	
430	B85	dirty grey black ballast with sharp cobble stones	dense to very dense cobbles are well cemented with fine sand and silt
700	B86	well degraded black cinders	dense, original ballast
850	B87	brown sand with some gravel	very dense, original sub-ballast
900		brown silty sand	very dense subgrade

END OF PIT

Figure 5.2 Soil profile observed under tie at northwest corner of Clarke Side Road grade crossing, 1 m west of signal light, London Site A (Dundas Subdivision NP 73.97)



9

silty sand subgrade at a depth of 850 mm (34 in.). The excavation was terminated at about 900 mm (36 in.) and was relatively dry.

Site B, the control site without geotextile, revealed that the ballast had been, and probably still was, penetrating into the softer subgrade material. At the centreline of the track there was a 25 mm (1 in.) gap under the tie (i.e. end bound). The soil horizons in the first 500 mm (20 in.) below the ties were concave, with the low points found directly below the rail seats. The material directly below the ties was a dark slag ballast of thickness between 50 and 100 mm (2 and 4 in.). Below the slag there was approximately 425 mm (17 in.) of compact to dense dirty ballast. The colouration changed from a brownish-grey to a greyish-black at about 200 mm (8 in.) below the base of the ties at the centreline of the track, in contrast to a depth of about 375 mm (15 in.) below the base of the ties under the rail seats. The dirty ballast was underlain by 250 mm (10 in.) of dense, black, degraded cinders followed by about 150 mm (6 in.) of dense to very-dense brown sand and gravel. These two layers were probably the original ballast and subballast layers which were founded on a very-dense, light-brown, silty sand subgrade. The pit excavation was terminated at 900 mm (36 in.) below the base of the ties.

The light-brown colouration observed in the dirty ballast between the 50 mm (2 in.) and 375 mm (15 in.) depths has been partly due to fine subgrade soil migrating from outside the track structure towards the active zone beneath the rail seat. The fine subgrade soil has been transported to this area by the excess water intruding from the unditched shoulders. The degraded ballast fines have mixed with the fine subgrade soil to effectively reduce the permeability of the ballast.

The two profiles have similar stratigraphy below a depth of about 250 mm (10 in.). Their major differences above this point are reflected in the geotextile installation procedure and the degree of particle mixing below the track. It was apparent that the track had been excavated to a depth of about 225 mm (9 in.) below the base of the ties. The geotextile was placed between two layers of sand and gravel for protection against puncture damage. The fine-grain particles in the granular fill reduced the effect of subgrade contamination but, unfortunately, that

was not the sole source of the problem. Both sites showed a great deal of contamination from fine brown subgrade soil that had migrated from the shoulder area. Water had clearly been draining towards the track instead of away from it.

A comparison of the effect of the geotextile on the grain size distribution of the ballast for these two sites was not relevant, since at site A the geotextile was covered with a sand and gravel layer for protection. This sand and gravel layer was not installed at site B. The finer material of the layer (i.e. the sand fraction) which was placed above the geotextile has mixed with the ballast, distorting the ballast grading curve. One point worth noting is the particle size distribution of the fines ultrasonically cleaned from the geotextile. The larger sizes range up to 10 times the EOS of the geotextiles, which clearly indicates that many of the particles were forced into or through the geotextile. These penetrating particles no doubt facilitated internal abrasion of the geotextile, leading to the high degree of abrasion shown in Plate 5.4.

This crossing requires better subsurface drainage control to ensure that surface water seeping into the ground does not stay in or beside the track structure. The geotextile installation did not guard against fouling from the shoulder material. As noted earlier, the ties were level with the surrounding terrain, which places the geotextile about 350 mm (14 in.) below the ground surface. If shoulder ditches are not possible in this type of flat topography, then French drains should be installed in or close to the shoulders. A standard procedure for constructing French drains involves excavating a shallow, narrow trench beside the prepared undercut surface and extending the width of the geotextile so it will adjoin a trench wall of the French drain. The open trench is then lined with a geotextile (generally lightweight) and backfilled with clean, coarse aggregate covered over with the geotextile. The enclosed granular drain is then protected from infiltrating subgrade soil. It should provide adequate drainage of the moisture away from the upgraded track structure. If no suitable discharge ditch is available for the French drain, a soakaway pit (a deepish excavation filled with coarse rubble which is sometimes lined with a geotextile) should be constructed some distance from the track, into which the French drains are discharged.

5.2.2 Kingston Subdivision, MP 218.18,
Elmwood Drive, Belleville

The track structure at this grade crossing was in reasonable condition at the time of the preliminary site visit. Fine soil particles were noticeable at the surface -- an indication of poorly drained track -- but the track structure was performing reasonably well under the existing traffic loads. The ditches were shallow and the shoulders fairly wide at the crossing. Local drainage was inhibited to the west of the crossing as the track entered a cut section.

The detailed site visit was made on September 22, 1981. At that time it was learned that both tracks had been upgraded with Terrafix 300N and new ballast. The south track was upgraded in 1977 and the north track was improved the following year.

Soil profiles were established for both tracks. These were obtained under the south shoulder rail, east of the grade crossing, and under the north shoulder rail, west of the grade crossing. The excavations, were labelled site A and site B, respectively, and are shown on the site plan in Figure 5.6. The soil stratigraphy for these two sites is shown in Figures 5.7 and 5.8 and the grain-sized distributions in Figures 5.9 and 5.10, respectively.

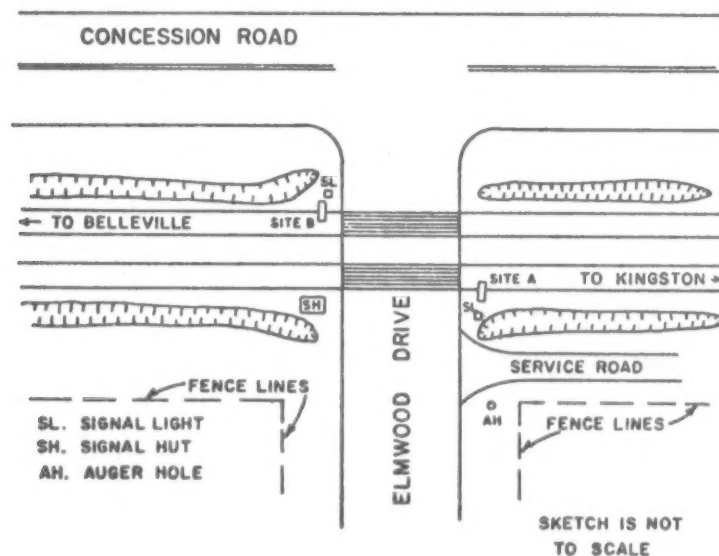


Figure 5.6 Site plan of Elmwood Drive grade crossing
(Kingston Subdivision MP 218.18)

DEPTH BELOW TIE (mm)	SAMPLE DEPTH	SOIL DESCRIPTION	COMMENTS
0			
	B52	dirty brown grey slag ballast some sand	B51 was sampled at the same depth as B52 but at the end of the tie ballast particles are cemented with fine silt
175	G53	Terraflux 300H	
300	B54	dirty grey dolomite ballast	rounded stones to cobbles cemented by caked fine particles
450	B55	dark grey gravel with some sand	
600	B56	dark grey sandy gravel	
660	B57	grey sandy gravel, some silt	

END OF FIT

Figure 5.7 Soil profile observed under tie at south-east corner of Elmwood Drive grade crossing adjacent signal light, Belleville Site A (Kingston Subdivision MP 218.18)

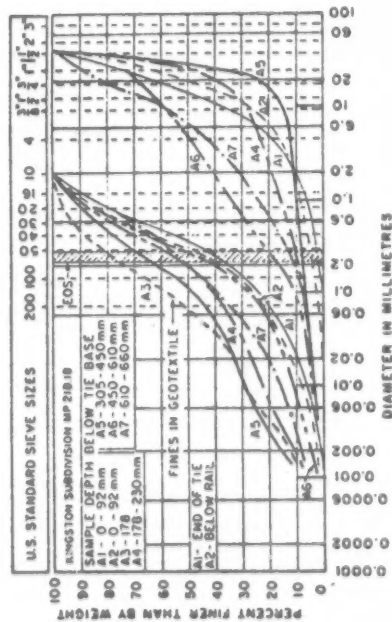


Figure 5.9 Grain size analysis of soil samples from Elmwood Drive crossing south track, Belleville Site A (Kingston Sub-division MP 218.18)

DEPTH BELOW TIE (mm)	SAMPLE DEPTH	SOIL DESCRIPTION	COMMENTS
0			
	B82	dirty brown grey slag ballast	B51 was sampled at the same depth as B82 but at the end of the tie brown mud has caked around the tie
350	B83	dark grey slag ballast	the geotextile has been doubled over below the north rail of the crossing
	G84	Terraflux 300 N	
600	B85	dark grey dolomite ballast some sand fines	
700	B86	grey sandy gravel	

END OF FIT

Figure 5.8 Soil profile observed under tie at north-west corner of Elmwood Drive grade crossing adjacent signal light, Belleville Site A (Kingston Subdivision MP 218.18)

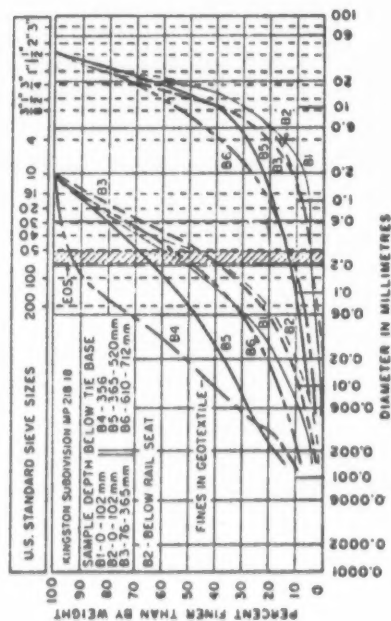


Figure 5.10 Grain size analysis of soil samples from Elmwood Drive crossing north track, Belleville Site B (Kingston Sub-division MP 218.18)

Fine silt and clay particles were observed around the removed tie at site A as shown in Plate 5.5. This condition is generally due to either surface fouling from wind-blown fines, or fines transported by surface runoff from the track shoulders into the track structure or fines permeated through the geotextile. The majority of the fines were, however, foreign to the ballast or subballast aggregate and are not due to aggregate degradation, since the mineralogy was different. There was approximately 175 mm (7 in.) of dirty brownish-grey ballast between the base of the ties and the geotextile, as shown in Plate 5.6. Much of the ballast has been degraded to a dense granular state, resulting in considerably-reduced drainability. Significant geotextile damage was found directly below the rail seat and tie. Plate 5.7 illustrates the damaged condition of the geotextile. Sufficient damage is evident that some migration of fines upwards through the geotextile would be possible, indeed even probable, in view of the drainage conditions.

Below the geotextile, there was a buildup of a fine-grained soil matrix which was cemented into the dirty ballast as shown in Plate 5.8. The old ballast material beneath the geotextile was identified as a dolomite aggregate and appeared to be mixed with a dark grey sand from the geotextile level to a depth of about 300 mm (12 in.) below the base of the ties. Below 300 mm (12 in.), the dark-grey sand had a small percentage of gravel material which developed into a dark-grey, sandy gravel at about 450 mm (18 in.). The granular fill was underlain by a very-dense, grey, clayey sand, thought to be the original subgrade material. The transition was at 600 mm (24 in.) below the base of the ties and remained that way to the end of the pit at 660 mm (26 in.). The pit was relatively dry but exhibited damp soils throughout.

The results of the grading curves obtained from site A are given in Figure 5.9. Sample A4 just below the geotextile is that of the badly-fouled ballast which has clearly mixed with the rising brown-coloured fines from the underlying material, since neither slag nor dolomite ballast breaks down into brown-coloured fines. The mineralogy was also different. The geotextile has clearly prevented the majority of the fines from rising, thus causing an accumulation in sample A4, as evident in Plate 5.8. The coarseness of sample A5 is such that under-

lying fines would have no difficulty passing through its voids, either by being washed downwards or piped upwards.

The conditions in the north track, site B, were similar to those of the south track, except that the geotextile was placed lower down in the structure at a depth of 350 mm (14 in.) below the base of the ties. The dark ballast directly beneath the ties was discoloured a light brown by fine-grain soil particles filtering down from the surface into the gaps around the ties. The ballast was cleaner at this site, particularly just above the geotextile. The degraded particle fines were coarser at site B and were not cemented together. In part, this may well have been due to the deeper position of the geotextile, more effectively dissipating the underlying pore pressures.

At site B, below the rail seat excavated only, the geotextile had been doubled over because the geotextile's width was about 1 m (1 yd) greater than the width of the installation excavation. The added thickness helped maintain a cleaner ballast above the geotextile, as shown in Plate 5.9. The geotextile experienced only minor puncture damage at this depth. As seen from the soil profile recorded in Figure 5.8, the dark-grey ballast with some sand existed below the geotextile and was similar to that of site A. The ballast material was underlain by a grey sandy gravel at 600 mm (24 in.). The pit excavation was terminated at about 700 mm (28 in.) below the base of the ties and was relatively dry, but again the soil was damp throughout.

The north track grading curves shown in Figure 5.10 may be compared to those in Figure 5.9 for the south track, and confirm the observations of a cleaner ballast profile with the deeper geotextile installation of the north track. The less-abraded geotextile from the deeper installation also displayed lower percentages of coarse material trapped in the geotextile than the shallower south track installation. In part this is believed due to the lower stresses forcing fewer particles into the deeper geotextile, as seen by comparing the curves of trapped fines in the geotextiles, and thus causing less internal abrasion of the fibers.

5.2.3 Kingston Subdivision, MP 213.45, Shannonville Road, Belleville

The north track of the Shannonville Road grade-crossing was upgraded in 1976. The geotextile was installed at that time to reduce the pumping

condition at the crossing. Details of the maintenance required at this site, both before and after the installation, were not made available; however, it was indicated that the required maintenance had been decreased since the installation of the geotextile. It is assumed that the crossing received the same annual tonnage as the Elmwood Drive crossing (MP 218.18), located approximately 7.5 km (4.7 miles) west of the Shannonville Road crossing (MP 213.45). The annual tonnage has therefore been assumed as 15.5 million gross tonnes (17.1 MMGT), which places the total estimate at over 77 million gross tonnes (85 MMGT) at the time of the field visit.

The crossing is situated in a shallow cut area. Side ditches were established about 1 meter (3.3 ft) away from the shoulders. The ditches were shallow and have become overgrown with vegetation. There were no visible signs of subsurface drainage pipes leading from beneath either track.

The two mainline tracks were in reasonable condition, with a few localized pumping areas at some of the rail joints. The north track, upgraded in 1976 with a geotextile, was visibly contaminated with pumping fines on the surface of the leaving side of the crossing, as shown in Plate 5.10. The cracks in the cross-ties were wet, indicating that excess water periodically ponded near the surface.

The site visit was completed on September 22, 1981 (the same day as those at Elmwood Drive). The second tie west of the crossing, in the immediate area of the pumping fines, was pulled for the track assessment. The underside of the tie was damp and the ballast around the tie remained cemented in place by fines. The observed soil profile for this site is shown in Figure 5.11 and the grading curves of the obtained samples in Figure 5.12.

The entire 200 mm (8 in.) of ballast above the geotextile was fouled with brown silts and sands. There were dolomite aggregate particles mixed in with the slag ballast. This mixture is not considered good because the harder slag particles tend to grind the dolomite more quickly, producing more fines in the upper part of the ballast structure. Plate 5.11 illustrates the perched water that was encountered approximately 50 mm (2 in.) above the geotextile, indicating poor

DEPTH BELOW TIE (mm)	SAMPLE DEPTH	SOIL DESCRIPTION	COMMENTS
0			
200	BS1	dirty slag ballast with brown fines throughout	very wet, cemented ballast, dolomite particles are sized with the slag
	BS2		
	GS3		
450	BS4	Terrafix 3008 cemented dolomite ballast	top 75 mm is a brown grey clayey silt cake, dense dirty ballast below
550	BS5	dark brown sand and gravel	dense to very dense subgrade

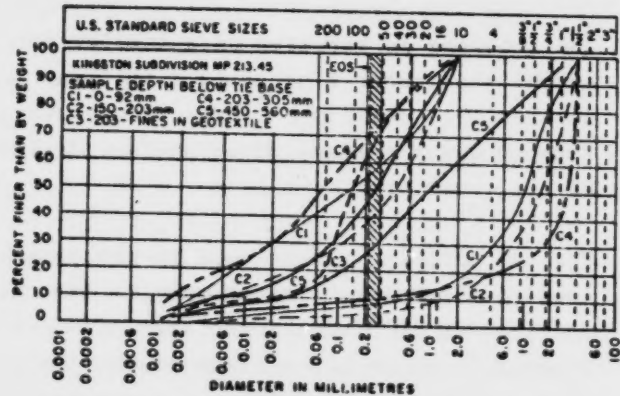
END OF PIT

◀ Figure 5.11

Soil profile observed
under tie at northwest
corner of Shannonville
Road grade-crossing 1 m
west of end of crossing
planks, Belleville Site C
(Kingston Subdivision MP
213.45)

Figure 5.12 ▶

Grain size analysis of soil
samples from Shannonville
Road crossing north track,
Belleville Site C (Kingston
Subdivision MP 213.45)



shoulder drainage in the system. The dirty ballast was clogged with fines at this depth and down to the geotextile.

Although the geotextile was overlapped (doubled) below the rail seat excavated, it was badly clogged and punctured. There was a dense brownish-grey filter cake layer just below the geotextile which merged with a dense, dirty, grey ballast below. At 450 mm (18 in.) below the ties, the old ballast became mixed with a dark-brown sand and gravel which continued downwards to the termination of the pit excavation at 550 mm (22 in.). This very dense material was considered to be the original subgrade soil. The subsurface soil conditions confirmed the visual impression that there was insufficient lateral drainage of the crossing. The shoulder end of the wall to the test pit illustrated that any lateral drainage must pass through a low permeability, fine, brown, sandy, silt shoulder material. With the ditch about 1 meter (3.3 ft) away from the ballast, this wall of less-permeable shoulder material acted to hold the water inside the track structure, causing flooding of the track-bearing area. This problem would have been alleviated if the side shoulders had been flattened during installation

of the geotextile and the geotextile had been draped towards the ditches so that lateral drainage could occur under gravity.

The grading curves shown in Figure 5.12 basically confirm the visual observations recorded in Figure 5.11. Samples C1, C2 and C4 are clearly a mixture of coarse aggregate which has been fouled with finer material, with over 20 per cent passing the 5 mm sieve (No. 4). The dark-brown nature of the fines suggests that at least some of the fouling has been migration from the subgrade, since dolomite ballast does not break down to produce dark-brown coloured fines.

5.2.4 Napadogan Subdivision, MP 200.10, 200.40
and 204.78, near Quisibis, New Brunswick

The installations in northern New Brunswick were revisited on September 15, 1981. The weather conditions had been wet the previous evening, with overcast skies in the morning changing to clear skies in the afternoon. The purpose of this return visit was to inspect and sample the soil and geotextile conditions along a half-mile installation over a flood plain with high water table. Discussions with the local maintenance personnel indicated that, when comparing sites upgraded at the same time, less tie maintenance had been observed on the track rehabilitated with geotextiles as opposed to that rehabilitated without geotextiles.

The track was constructed beside the main highway on a separate embankment. There were only two locations along this section of track that had suitable access from the road. The first site was a private crossing at approximately MP 200.1, referred to as site A. The second was at a similar crossing near MP 200.4, referred to as site B. The first site had Terrafix 300NA in-track, while the second site did not have any geotextile in-track. Their soil profiles are shown in Figures 5.13 and 5.14 respectively, and visually in Plates 5.12 and 5.15 respectively. The grading curves are shown for each site in Figures 5.15 and 5.16 and the grading curves in the upper 300 mm (12 in.) of the track stratigraphy compared in Figure 5.17.

The pit with geotextile was located below one of the ties, just at the end of the private crossing at MP 200.1. Prior to excavation, the geotextile depth was located by digging just off the end of a tie as shown

DEPTH BELOW TIE (m)	SAMPLE DEPTH	SOIL DESCRIPTION	COMMENTS
	381	Dolomite limestone ballast with fine particles throughout	The ballast was relatively clean but degraded. The degraded particles have settled to the zone just above the geotextile.
300	382		There are ballast particles below the geotextile
350	383	Terraflax 300MA	
425	384		The clean brown compact sand filter showed some mixing at both top and bottom.
	385	gray sandy gravel	typically dense to very dense, deep granular fill underlain by a very dense gray brown river gravel fill with smooth cobble throughout
850	386	gray brown gravel with cobble	water level at 840 mm below base of tie
950			

END OF PIT

Figure 5.13 Soil profile observed under tie at private road crossing located about 8 km east of Quisibis, M.B., Site B (Napadogan Sub-division MP 200.1)

DEPTH BELOW TIE (m)	SAMPLE DEPTH	SOIL DESCRIPTION	COMMENTS
0	381	dirty brown gray dolomite ballast changing to brown sand and gravel	The ballast was fouling from shoulder material and mixing in the lower region with the brown sand filter.
300	382	ballast	
	383	brown sand	The dense brown sand was mixing with the ballast above and the gray sandy gravel below.
350		gray sandy gravel	dense to very dense, deep granular fill underlain by a very dense gray brown river gravel fill with smooth cobbles throughout.
950	384	gray brown gravel with cobble	
900			

END OF PIT

Figure 5.14 Soil profile observed under tie at private road crossing located about 7 km east of Quisibis, M.B., Site B (Napadogan Sub-division MP 200.4)

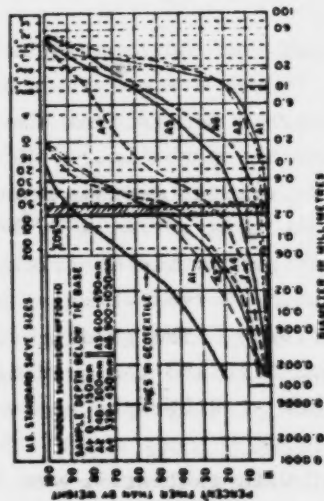


Figure 5.15 Grain size analysis of soil samples from crossing near Quisibis, M.B., Site A. (Napadogan Subdivision MP 200.1)

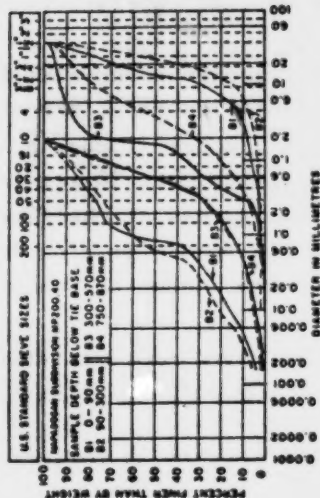


Figure 5.16 Grain size analysis of soil samples from crossing near Quisibis, M.B., Site B. (Napadogan Subdivision MP 200.4)

in Plate 5.13. The ballast at this location was relatively clean between the ties but there was some degradation and fouling with sand under the tie base, as is evident from the grading curves of samples A1 and A2 in Figure 5.15. The ballast beyond the end of the ties was slightly cleaner than that below the ties. The smallest of the particles had settled towards the geotextile, resulting in a small filter cake system above the geotextile. The geotextile was at a depth of about 300 mm (12 in.), and was found to be in good condition. There were about 30 mm (1.2 in.) of ballast badly fouled with cleanish brown sand below the geotextile as shown in Plate 5.14. The soil then changed to a clean brown sand containing some gravel sizes, as is evident from the grading curve of sample A4. Apparently, the old ballast was removed to a depth at or near the sand filter layer before the geotextile was installed. The brown sand layer was about 150 mm (6 in.) thick. It began mixing with grey sandy gravel at about 485 mm (19.4 in.) below the base of the ties. The dense granular fill changed to a very dense greyish-brown river gravel at the 850 mm (34 in.) level. Water was encountered in the pit at about 940 mm (37.5 in.) and the last sample from the pit was taken at a depth of 950 mm (38 in.). The grading curves of the grey sandy gravel (A5) and very dense river gravel (A6) are shown in Figure 5.15.

The profile clearly showed that the geotextile was containing the sandy soil from below. Although some sand was penetrating through the geotextile at the rail seat, as seen in Plate 5.12, the geotextile was maintaining a relatively clean, dry ballast below the ties while the water level was less than a meter (40 in.) below the base of the ties.

The second location, which had no geotextile, was at MP 200.4. The track's surface appearance was similar to the first site. As recorded in Figure 5.14 and as seen in Plate 5.15, the ballast layer at this second site was about 300 mm (12 in.) thick, similar to the first site. Although not too evident from the comparison of total grading curves shown in Figure 5.17, the difference between the two sites was the visibly-noticeable increase of fines in the upper region of the ballast at the second site without the geotextile in-track. This difference is more apparent from a comparison of the minus 2 mm (No 10) sieve material also shown in Figure 5.17. Below the dirty ballast of the second site there was 250 mm (10 in.) of dense brown sand whose

grading curve, B3, is shown in Figure 5.16. It was clear that, subjected to traffic loading, the upper surface of the sand was mobilized upward through the ballast under the ties, especially under the rail seat. At the lower boundary of the brown sand the profile changed to a very dense granular fill at about 550 mm (22 in.) below the base of the ties, whose grading curve, B4, is also shown on Figure 5.16. This transition area was visibly ill-defined due to the particle mixing. It was, however, moist to wet due to the change in porosity from the sand layer to the more dense gravel layer. The granular fill was underlain by the greyish-brown river gravel at about 850 mm (34 in.) below the ties. The pit was terminated at 900 mm (36 in.) without having encountered a water table.

These two sites proved to be useful as a comparison of similar sites with and without geotextiles. There was an obvious improvement in the ballast section with the geotextile in-track, since the geotextile had restrained the finer material from coming up and fouling the ballast in spite of the higher water table. Both track locations appeared to have reasonable drainage to the shoulder areas. Fine soil particles were not entering the system from the shoulder as observed at the Ontario sites. Indeed, the ballast at the ends of the removed ties was relatively clean.

A third site, known as site C, was examined during the site visit to increase the data base on in-track use of Terrafix 300NA. This site was the grade crossing at MP 204.78 which had been inspected earlier and found to have stable track conditions, despite potential problems with drainage at the crossing.

The notes taken during the preliminary site visit indicated that the geotextile had not been extended very far beyond either end of the crossing. It was estimated that the geotextile extended no more than one meter (40 in.) on either side of the planking. Thus the excavation was located under the first tie east of the crossing. The soil profile below the end of this crossing is shown in Figure 5.18 and the grading curves of the samples recovered from the excavation are shown in Figure 5.19. The grading curves of the samples taken from above the geotextile are compared with those at MP 200.4 without a geotextile in Figure 5.20.

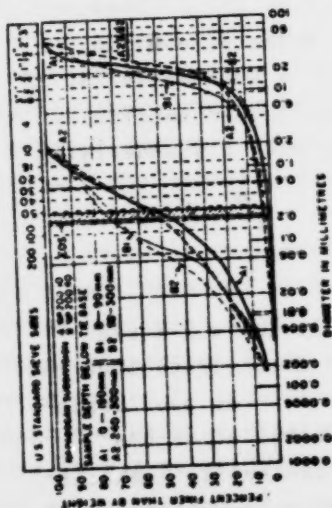


Figure 5.17 Comparison of grain size analysis of the two upper samples from Quisibis, M.B., Sites A and B (Napadogan Subdivision MP 200.1 and 200.4)

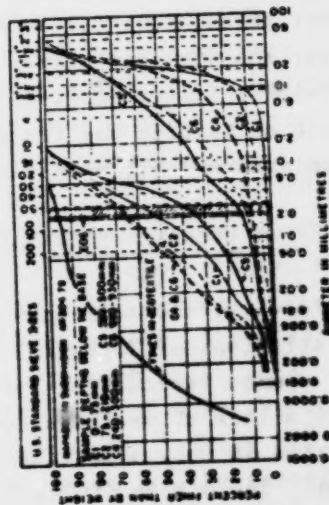


Figure 5.19 Grain size analysis of soil samples from crossing in Quisibis, M.B., Site C (Napadogan Subdivision MP 204.78)

DEPTH BELOW TIE (m)	SAMPLE DEPTH	SOIL DESCRIPTION	COMMENTS
0	BS1	dirty brown grey dolomite ballast	The percentage of brown fine sand and silt was increasing with depth. Ballast was very wet near geotextile.
250	BS2		
	BS3	Tortafix 3005A	
300	BS4	dirty brown grey dolomite ballast	very wet silty ballast cake below geotextile
	BS5	dark grey degraded clinders	very dense clinder layer beneath filter call
500		brown grey sand and gravel fill with cobbles throughout	The very dense granular soil was old fill.
950	BS6		

END OF PILE

Figure 5.18 Soil profile observed under tie at grade crossing in Quisibis, M.B., Site C (Napadogan Subdivision MP 204.78)

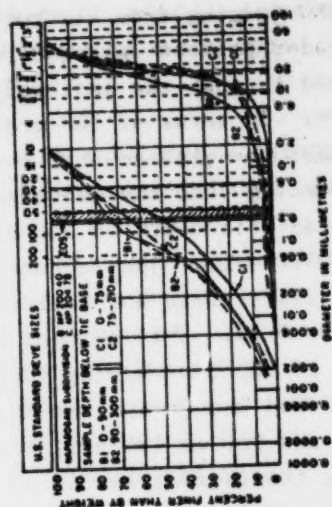


Figure 5.20 Comparison of grain size analysis of the two upper samples from Quisibis, M.B., Sites B and C (Napadogan Subdivision MP 200.4 and 204.78)

The grey Dolomite ballast was dirty with brown fine sand and silt, which, judging from its colouration, texture and mineralogy, was not degraded ballast aggregate. These fines were assumed to have penetrated through the geotextile since their volume was increasing with depth. In terms of the grading curves compared in Figure 5.20, the ballast was cleaner than the crossing without a geotextile (site B), suggesting that the geotextile was of benefit. The geotextile was located at a depth of 250 mm (10 in.) under a thin moist layer of fine granular soil. The geotextile was underlain by about 50 mm (2 in.) of damp filter cake and ballast mixture with the grading shown by C4 in Figure 5.19. This changed to dark cinders at 300 mm (12 in.) below the base of the ties having the grading shown by C5. Very dense brownish-grey sand and gravel was found below the cinders, between 500 mm (20 in.) and 900 mm (36 in.) below the base of the ties, 900 mm (36 in.) being the termination of the pit. The grey sand and gravel had a grading curve very similar to the cinder mixture and is shown by curve C6. No water table was encountered in this pit.

The geotextile sample was in fairly good condition. There were a few worn holes in the geotextile, as shown by Plate 5.16, in the vicinity of the rail seat. Poor drainage conditions limited the lateral drainage and filtering abilities of the geotextile. The shoulders were fairly wide at this location and no provision had been made to drain the water from the geotextile and track structure to the ditches, except through the contaminated fill material. Nevertheless, in comparison with the better-drained site B without a geotextile (at MP 200.4), it is evident that the geotextile was having the beneficial effect of keeping the track ballast from fouling with the underlying brown sand and ultimately with the cinders.

5.3 OVERALL PERFORMANCE

Upon review, the soil and geotextile conditions at the six field installations of Terrafix 300N or Terrafix 300NA demonstrate that the most common reoccurring instability problem results from poor drainage. A lack of drainage considerations during installation has resulted in only a partial effectiveness of the geotextile installations. The 0.8 km (0.5 mile) section of track outside Quisibis, New Brunswick, which had poor drainage due to a high water table, showed the importance of installing the geotextile so that it may drain the

moisture to the shoulders and into the deep side ditches. Clarke Side Road crossing at London demonstrated the necessity of providing drainage to a soakaway pit if local topography is adverse to ditch-type drainage.

The other sites were at grade-crossings where wide embankments existed at the junction of the road and rail surfaces. Extra work should have been incorporated into the crossing rehabilitation to deal with the poor drainage. Unfortunately this was not done, with the result that the soil beside the track has been transported by the surface water into the track, creating problems in the ballast structure. In most cases, the geotextile was installed below the surrounding ground surface without provision for allowing lateral flow from the geotextile to French drains or drainage ditches. The sites have shown that in addition to any soil that may be pumped upwards through the track support, fine soil particles are washed, by seeping surface water, into the open ballast structure from the shoulders, fouling the ballast with the piping soil and softening the subgrade with the additional retained water. This inward flow of water is highly detrimental and would have to be reversed for any longevity of track improvement.

One of the contributing factors to a geotextile's performance in-track is the depth at which it is placed below the base of the ties. It is well known that the intensity of pressure generated by a standard wheel load decreases with depth as it is distributed through the track structure. Depending on the abrasive resistance of the geotextile, ideally there should be an optimum depth at which a geotextile can be installed during a track upgrading program that will economically minimize the damaging effects of ballast punctures and abrasion.

Such a depth is suggested by the conditions of the geotextiles at the six sites installed with needle-punched, resin-dipped geotextiles, all having unit area mass (weight) of about 500 g/m^2 (14.7 oz/yd^2). The estimated percentage of geotextile damage for each sample of geotextile was obtained by tracing the outline of the worn-through holes onto paper and using a planimeter to obtain the percentage of worn through area in the worst $300 \text{ mm} \times 300 \text{ mm}$ ($1' \times 1'$) square area. These values are shown in Table 5.1 as a percentage of total damage to the geotextile. The values range from 0.3 per cent at a depth of 350 mm (14 in.)

to 4.1 per cent at a depth of 175 mm (7 in.), which clearly indicate that as the depth of ballast between the base of the ties and the geotextile is reduced, the amount of damage that the geotextile receives is increased.

TABLE 5.1

EFFECT OF DEPTH ON WEAR IN WORST 300 MM X 300 MM
(1' x 1') GEOTEXTILE AREA
(needle-punched, resin-dipped geotextile,
450 x 510 g/m² (13 to 15 oz/yd²))

Site	Excavated Depth*	Years in Track	Total Tonnage	Number of 5mm holes	Per Cent Worn Area	Comments
Dundas, MP73.97, London A	150 mm 6 in	5 yrs	76x10 ⁶ tonne 84x10 ⁶ ton	30	2.8	1 large hole over 12 mm (0.5 in.) dia.
Kingston, MP218.18, Belleville A	175 mm 7 in	4 yrs	63x10 ⁶ tonne 69x10 ⁶ ton	34	4.1	4 large holes over 12 mm (0.5 in.) dia.
Kingston, MP213.45, Belleville C	200 mm 8 in	5 yrs	78x10 ⁶ tonne 86x10 ⁶ ton	31	2.0	9 large holes over 12 mm (0.5 in.) dia.
Wapadogan, MP204.78, Quisibis C	250 mm 10 in	3 yrs	37x10 ⁶ tonne 41x10 ⁶ ton	26	1.0	
Wapadogan, MP200.1, Quisibis A	300 mm 12 in	3 yrs	37x10 ⁶ tonne 41x10 ⁶ ton	10	0.6	some cuts
Kingston, MP218.18, Belleville B	350 mm 14 in	3 yrs	46x10 ⁶ tonne 51x10 ⁶ ton	5	0.3	some cuts

* add 50 mm (2 in.) for installation depth.

As a confirmation of the visual damage of the air-dried but uncleaned geotextile samples used for obtaining Table 5.1, a 125 mm (5 inch) diameter sample of intact material from below each rail seat (actually used for permeability assessment in the fouled and then cleaned state) was ultrasonically cleaned and assessed for particle intrusion holes by means of optical measuring techniques. The results from such a quanti-

tative assessment may be qualitatively verified by placing the geotextile sample in a new and used state in front of a lighted background as shown in Plate 5.17. The observed quantitative data is shown in Table 5.2 and confirms the findings of Table 5.1. It also shows that the in-track opening size of a geotextile is greater than that of the new material, which, although having an EOS of 0.21 mm (No. 70 sieve), was thick enough to prevent, as seen in Plate 5.17, the visual observation of any continuous holes.

TABLE 5.2

HOLES APPARENT IN ULTRASONICALLY-CLEANED GEOTEXTILE
APPEARING INACT WHEN DIRTY
(needle-punched, resin-dipped geotextile,
450 x 510 g/m² (13 to 15 oz/yd²))

Site	Excavated Depth*	Years in Track	Total Tonnage	Per Cent of Geotextile Geotextile Sample with Holes Having Sizes:**			Number and Size of Larger Holes
				0-0.1 mm	0.1-0.2 mm	0.2-0.3 mm	
Dundas, MP73.97, London A	150 mm 6 in	5 yrs	76x10 ⁶ tonne 84x10 ⁶ ton	64.6	10.4	15	2 @ 0.4 mm 1 @ 0.5 mm 1 @ 0.6 mm 1 @ 0.7 mm 1 @ 0.8 mm
Kingston, MP218.18, Belleville A	175 mm 7 in	4 yrs	63x10 ⁶ tonne 69x10 ⁶ ton	74.4	25.6		1 @ 0.4 mm 1 @ 0.6 mm
Kingston, MP213.45, Belleville C	200 mm 8 in	5 yrs	78x10 ⁶ tonne 86x10 ⁶ ton	87.0	13.0		1 @ 0.4 mm 1 @ 0.5 mm
Napadogan, MP204.78, Quisibis C	250 mm 10 in	3 yrs	37x10 ⁶ tonne 41x10 ⁶ ton	99.9	0.1		nil
Napadogan, MP200.1, Quisibis A	300 mm 12 in	3 yrs	37x10 ⁶ tonne 41x10 ⁶ ton	N/A			no holes of any size apparent
Kingston, MP218.18, Belleville B	350 mm 14 in	3 yrs	46x10 ⁶ tonne 51x10 ⁶ ton	93.0	7.0		1 @ 1.6 mm

* add 50 mm (2 in.) for installation depth

** maximum spacing between holes for continuity taken as 5 mm

The effect of depth with respect to geotextile damage given in Table 5.1 can be illustrated graphically, as shown in Figure 5.21. The majority of the plotted values indicate an almost linear relationship between depth and per cent damage to a depth of 250 mm (10 in.). Below 250 mm (10 in.), the rate of change in per cent damage to the geotextiles is considerably decreased, which suggests that most of the observed damage below this depth originated during the installation period and not during the in-service life.

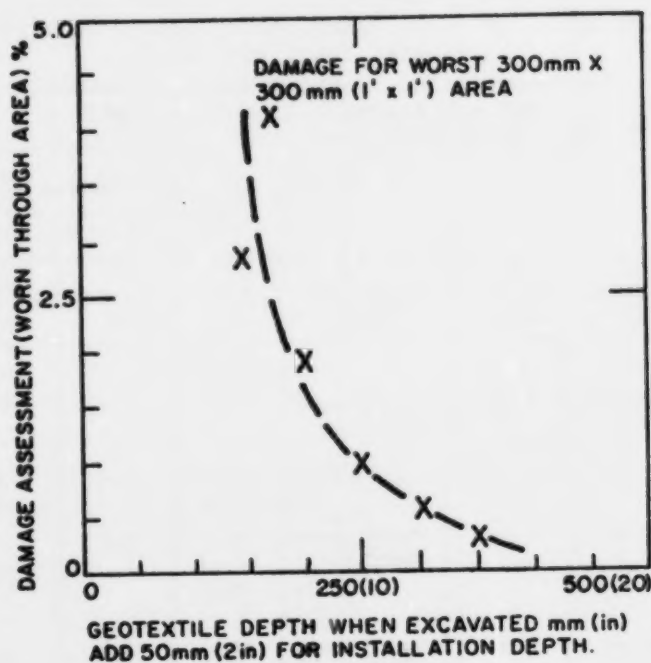


Figure 5.21 Measured geotextile worn through damage related to depth for Terrafix 300 type geotextiles

It should be noted that some of these geotextiles have been in service for up to five years. During that time, the tracks could have settled as much as 50 mm (2 in.) due to degradation and further compaction of the new ballast above the geotextile. In some cases, there has been additional ballast placed on the track since the original installa-

tion. With this in mind, a comparable installation depth should be taken as 300 mm (12 in.) or greater.

Finally, all the sites visited were installed with relatively heavy Terrafix resin-dipped geotextiles. It is worth noting that the maintenance crews all observed less tie maintenance at the sites with this relatively heavy geotextile as opposed to sites upgraded at the same time but without geotextiles.

5.4 GEOTEXTILE PERMEABILITY RESULTS

The geotextiles removed from the field were all subjected to 'as delivered' lateral permeability tests. Then the permeability specimen was cleaned in an ultrasonic bath using several changes of water until no further fines were removed by the cleaning process. The cleaned sample was tested for its lateral permeability. In addition, new samples of the geotextile were tested. Since the geotextile in the field would be subject to compression under load, all the geotextiles were tested under a variety of confining pressures which ranged in value over those likely to be experienced by a track subgrade below a tie directly subjected to a loaded freight car axle. The lateral permeability of the six geotextiles recovered from the excavations detailed in this chapter are presented in Figure 5.22.

Because some of the geotextiles recovered from the field were damaged under the rail seat, the permeability test samples of geotextiles removed from the field were cut from areas close to the rail seat but not at the rail seat, so as to obtain a test sample with no major damage. This meant that these samples were of variable distances away from the rail seat and thus a direct comparison of results was not possible. Indeed, even if all test samples were taken from the same distance from the rail seat, the permeability test results are more likely to have reflected the properties of the fouling fines than any position in the track bed, either in terms of depth below the ties or position in relationship to the rail seat.

Table 5.3 gives a summary of the ballast above and below each geotextile and the results of the tests of a new piece of material in comparison with a fouled sample tested under a normal load of 112 kPa

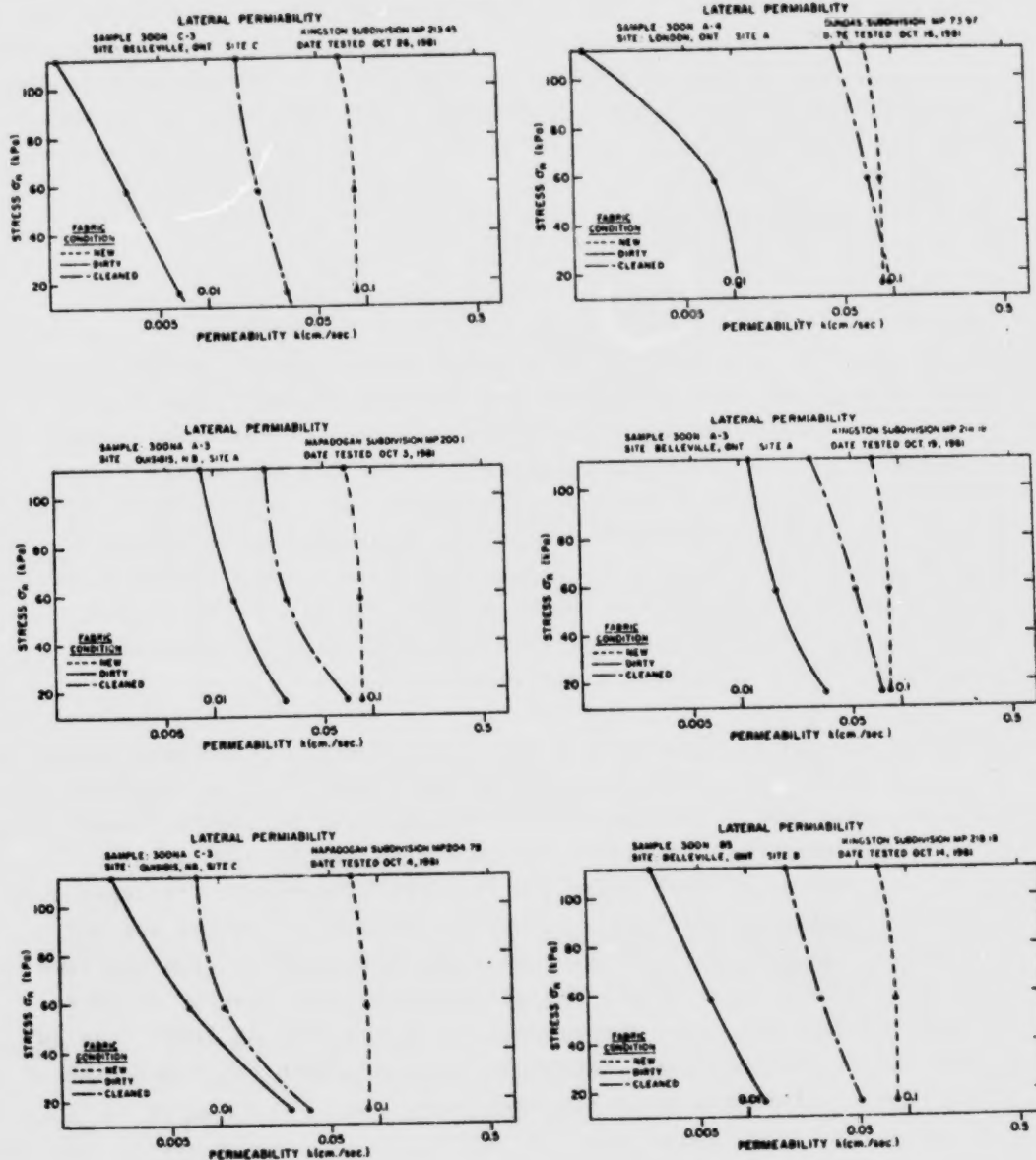


Figure 5.22 Results of lateral permeability on geotextiles recovered from CN tracks

(16.2 lb/in²) for each site. It may be seen that there is a substantial drop in the lateral permeability of all the field samples; the drop being in the range of 86 to 98 per cent. Thus, it seems reasonable to conclude that to maintain a good ability to drain water from the roadbed area only relatively thick geotextiles should be considered for future track-rehabilitation-type projects similar to those discussed herein. Indeed the heavyweight Terrafix materials must be regarded as lightweight relative to a geotextile needed for track rehabilitation.

TABLE 5.3

BALLAST DATA ADJOINING GEOTEXTILES AND PERMEABILITY
DATA FOR TESTS WITH 112 kPa (16.2 lb/in²) NORMAL LOAD

Site	Type of Ballast at Geotextile		Surface Drainage	Lateral Permeability		
	Above	Below		Virgin Sample (mm/s)	Field Sample (mm/s)	Per cent Change (%)
Dundas, MP73.97, London A	Slag, Dolo- mite, sand	Dolomite, sand, silt	flat, no ditches or sub-drains	0.599	0.012	98.0
Kingston, MP218.18, Belleville A	Dirty slag, sand	Dolomite, sand, silt	shallow ditches, no sub-drains	0.599	0.116	80.6
Kingston, MP213.45, Belleville C	Dirty slag, sand	Dolomite, sand, silt	wide shoulders, ditches, no sub-drains	0.599	0.012	98.0
Napadogan, MP 204.78, Quisibis C	Dirty Dolo- mite, sand	Dirty Dolo- mite, sand	wide shoulders, no sub-drains	0.599	0.022	96.3
Napadogan, MP200.1, Quisibis A	Dolomite	Sand, some dolomite	high embank- ment, good drainage	0.599	0.083	86.1
Kingston, MP218.18, Belleville B	Dirty slag	Limestone gravel	shallow ditches, no sub-drains	0.599	0.026	95.7

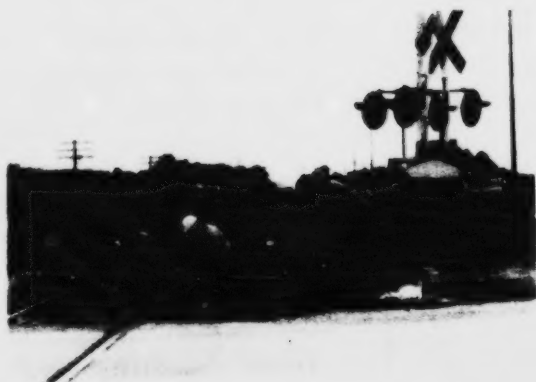


Plate 5.1 General conditions and location of test pits at Clarke Side Road, London, grade crossing (Dundas Subdivision MP 73.97)

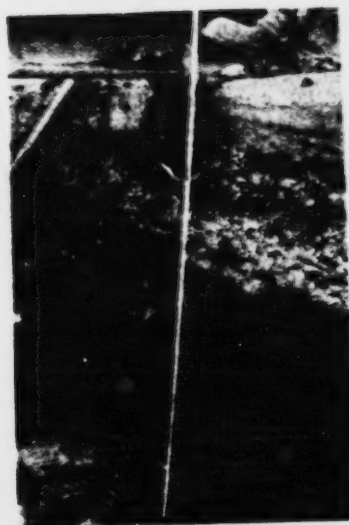


Plate 5.2 Soil profile at Clarke Side Road, London Site A, having geotextile (Dundas Subdivision MP 73.97)

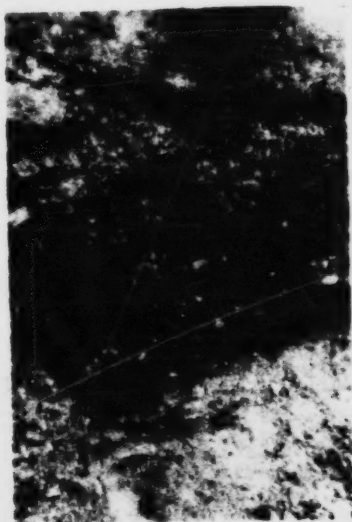


Plate 5.3 Soil profile at Clarke Side Road, London, Site B without geotextile (Dundas Subdivision MP 73.97)



Plate 5.4 Condition of geotextile at Clarke Side Road, London Site A (Dundas Subdivision MP 73.97)

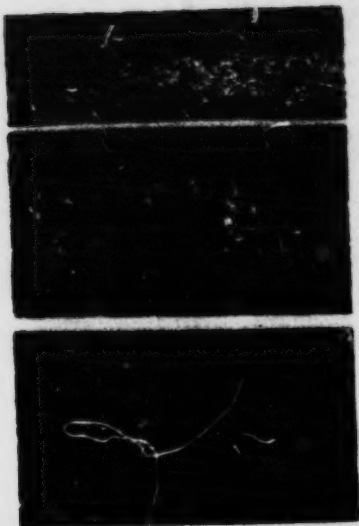


Plate 5.5 Condition of fouled ballast in contact with tie base at Elmwood Drive grade crossing, Belleville Site A (Kingston Subdivision MP 218.18)



Plate 5.6 Condition of ballast below rail seat and end of tie at Elmwood Drive, Belleville Site A, showing fouling by silt and clay particles (Kingston Subdivision MP 218.18)

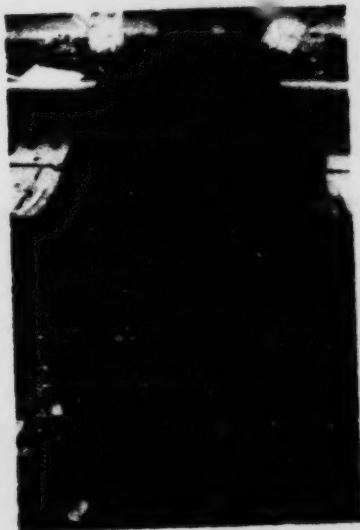


Plate 5.7 Condition of geotextile at Elmwood Drive, Belleville Site A (Kingston Subdivision MP 218.18)

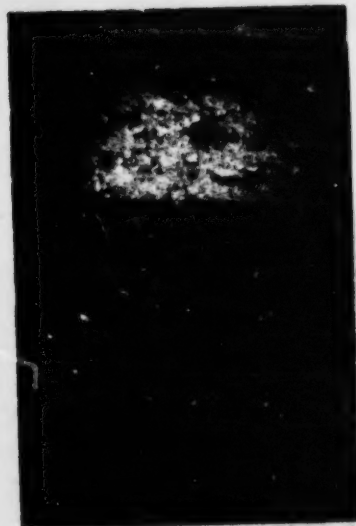


Plate 5.8 Filter cake formation below geotextile at Elmwood Drive, Belleville Site A (Kingston Subdivision MP 218.18)



Plate 5.9 Condition of ballast below rail seat and tie centreline at Elmwood Drive, Belleville Site B (Kingston Subdivision MP 218.18)

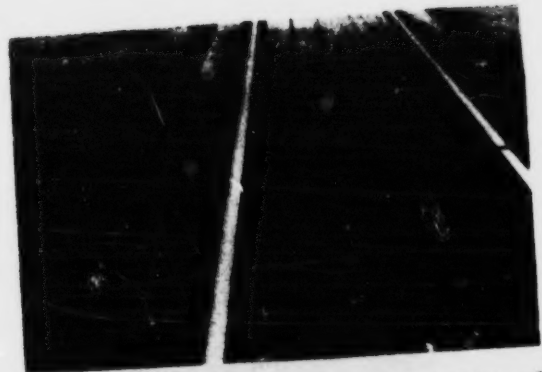


Plate 5.10 Surface condition and fouling of ballast at Shannonville Road grade crossing, Belleville Site C (Kingston Subdivision MP 213.45)

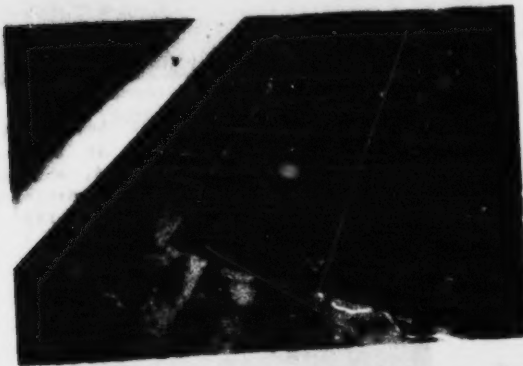


Plate 5.11 Perched water trapped 50 mm above geotextile at Shannonville Rd, Belleville Site C (Kingston Subdivision MP 213.45)



Plate 5.12 Ballast, sub-ballast and subgrade below rail seat with shovel at tie centreline of grade crossing, 8 km east of Quisibis, Site A (Napadogan Subdivision MP 200.1)



Plate 5.13 Excavation to locate geotextile depth prior to pit excavation at Quisibis Site A (Napadogan Subdivision MP 200.1)



Plate 5.14 Condition of geotextile and filter cake formation at Quisibis Site A (Napadogan Subdivision MP 200.1)



Plate 5.15 Test pit and soil profile at grade crossing 7 km east of Quisibis, Site B (Napadogan Subdivision MP 200.4)

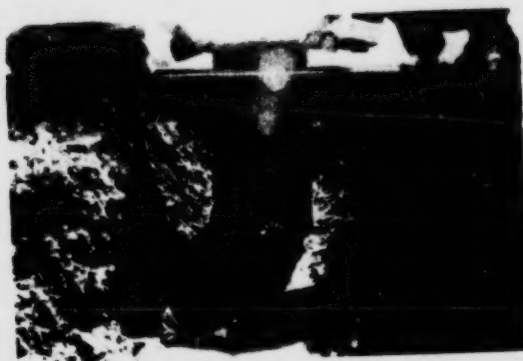


Plate 5.16 Condition of geotextile at grade crossing in Quisibis, Site C (Napadogan Subdivision MP 204.78)



Plate 5.17 Comparison of new (left) and used geotextile material backlit so as to show high density of fibres in new material versus particle penetration and internal wear of used material



CHAPTER 6

ASSESSMENT OF CONRAIL'S LOUDONVILLE TEST

6.1 INTRODUCTION

A second requirement of the geotextile field research program was, if time permitted, the observation of a variety of geotextiles under near-similar track conditions. The Loudonville test site enabled such an assessment of lightweight and mediumweight geotextiles to be made. This involved being a guest observer of an extensive geotextile test program at Loudonville, Ohio, conducted by Consolidated Rail Corporation, referred to hereafter as Conrail. Geotextiles were installed at the Loudonville test site in October 1979. Conrail had intended that all geotextiles would be installed in one continuous length of track near Loudonville, Ohio. One of the eight geotextiles was late in delivery and was subsequently installed 7.3 km (4.6 miles) from the other seven. Visits to the sites were made with the Conrail representatives May 19-20, 1981, and again on October 6-7, 1981. The information obtained during the two visits has proved invaluable by illustrating the combined effect of track drainage and geotextile selection for the stability of track structure.

6.2 METHOD OF INSPECTION

The method of inspection followed by Conrail at each geotextile location was as follows:

- . locate the section of track where a geotextile has been installed and select a tie for removal
- . remove the tie and ballast from above the geotextile
- . sample the ballast just below the tie and just above the geotextile, directly under the rail
- . cut and remove a geotextile sample from track
- . sample the ballast just below the geotextile, directly under the rail.

The ballast samples were transported to the Conrail laboratory for analyses. The geotextile samples were tested at one of the manufacturer's laboratories under Conrail supervision.

As guest observers, the writers photographed each geotextile location to illustrate track conditions prior to the investigation, ballast conditions above the geotextile, geotextile condition during removal, and ballast conditions below the geotextile. During a second visit, at the request of the writers, the ballast just below the geotextile was removed at some of the locations to expose the soil conditions further down in the track structure. Photographic records were made of these conditions. Some general site photographs were also taken to identify track locations with respect to topography and the drainage conditions.

A few field samples from below the rail seats of the pulled ties were obtained for analysis at Queen's University during the site investigation program. The samples were small due to transportation limitations.

6.3

GENERAL DETAILS

The Loudonville geotextile test site was located on mainline track in an area of gently undulating terrain. The track structure consisted of 70 kg/m (140 lb/yd) of continuous-welded rail placed on hardwood ties which were set at 500 mm (20 in.) spacings. A soft Dolomite was used for ballast. The composite results of the Los Angeles Abrasion and Mill Abrasion tests indicated that according to our classification (see CIGGT Report 79-4), it was a class D ballast, with a combined degradation value of about 57 per cent. The track history of this area has been pumping track and centrebinding ties due to poor subgrade and drainage conditions. The annual gross tonnage over the Loudonville test section was estimated to be about 23 million gross tonnes (25 MMGT) per year.

The geotextiles were installed during a track rehabilitation program of the eastbound (south) track. The Dolomite ballast was removed from the trackbed, mechanically cleaned to remove the finer particles from the ballast, and returned to the track structure on top of the rolled out geotextiles. Each roll of geotextile was between 80 and 100 meters

(275 and 330 feet) long. Seven types were installed end-to-end, east of MP 155, with approximately one meter (3.3 ft) of geotextile overlap at each transition point. The eighth roll was placed in-track at MP 151, which was approximately 7.3 km (4.6 miles) east of the main installation. An initial level survey was completed by Conrail at both sites for future settlement records.

The topography at the Loudonville site, while not exact, has been sketched in Figure 6.1. At the request of the writers, Conrail provided cross-profiles at the start of each geotextile and these are shown in Figure 6.2. It is believed that the topography had a direct effect on the observed performance of each geotextile. There were two cut sections noted on the site sketch in Figure 6.1, separated by a fill section. Plate 6.1 was taken facing west, with the camera positioned close to the starting point of the test site, while looking back at the fill section and away from the test section. The first cut section without geotextile, located to the west (left) in Figure 6.1, is in the distance. A side angle view of the fill section is shown in Plate 6.2. Both cut sections have similar surface drainage conditions and were assumed to have similar natural subsurface soil conditions below the track which is void of artificial drainage. The access road from the main road to the test site crossed the tracks from north to south just west of the fill section and followed east on the south side of the tracks (left side of the tracks in Plates 6.1 and 6.2) along a shoulder berm between the south toe of the track embankment and a flat swampy area. The crest of the embankment was about 2 meters (6.6 ft) above this wet soil. The geotextile test site is located in the right

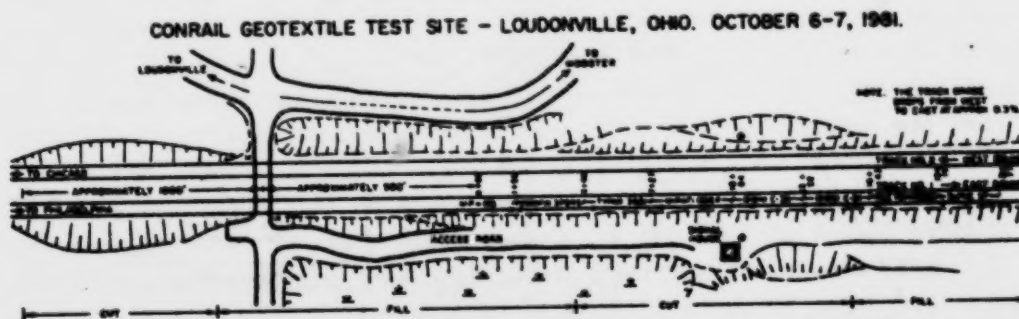


Figure 6.1 Schematic plan and topography of the Loudonville geotextile test site

track shown in Plates 6.3 and 6.4. Plates 6.3 and 6.4 were taken facing east with camera located at the start of the test section.

The test site started at the east end of the fill section and extended about 665 meters (2180 ft) east, through a cut section, finishing in another fill section. The track sloped gently downwards at about 0.3 per cent from west to east. The drainage conditions varied continually with the change in ground contours. Dry to damp conditions may be expected in the fill sections where the ballast was well drained by the granular embankment, while in the cut area there were inadequate shoulder ditches to allow for proper drainage of the tracks. Moist to wet track structure may, therefore, be expected throughout the cut section. Excess moisture would obviously have an adverse effect on the stability of the track structure. Thus, while each geotextile may appear to have been subjected to similar track loading, the subsurface conditions actually varied extensively according to the moisture content in the soil, subjecting each geotextile type to dramatically dissimilar impact loading and ballast movements.

A list of the geotextiles placed in-track at the Loudonville test site and some of their properties are tabulated in Table 6.1. Also included are some of their descriptive qualities which are believed pertinent to track applications.

6.4 CONTROL SITE WITHOUT GEOTEXTILES

A control site without geotextiles was established during the October test site visit. It was located just prior to the first geotextile installation at chainage (measured in feet from MP 155 towards MP 154) 1+44, in the first fill section of the test site. A general view of the excavation at the control site is shown in Plate 6.5. The horizons of cleaned ballast, what remains of the brown sand subballast and the dark-black pumping subgrade fines are clearly visible. A close-up view of the east (right side on Plate 6.5) side wall taken from the centre of track is shown in Plate 6.6. Evident is the fouling caused by the upward migration of the sand subballast under the rail seat. The fouling is also evident on the west side wall, views of which are shown taken from the centreline in Plate 6.7 and from the tie end in Plate 6.8. The ballast profile shown on the west side wall, Plates 6.7 and 6.8, revealed relatively clean dark-grey ballast for the first 150 mm

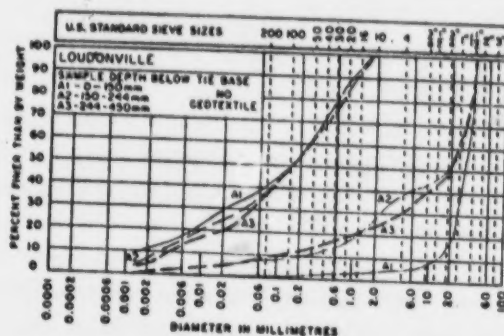
TABLE 6.1

SOME PROPERTIES OF GEOTEXTILES IN-TRACK AT LOUDONVILLE, OHIO

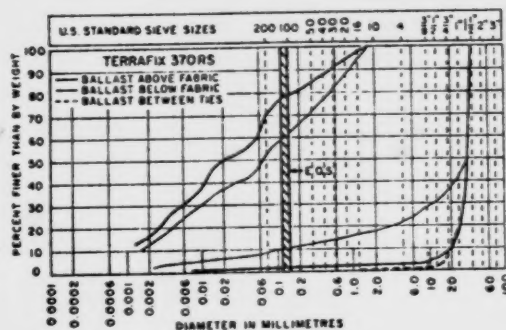
Product	Type	Fabric	Description	Weight g/m ² (oz/yd ²)	EOS mm (No)
Terrafix 370RS	non- woven	polyester	needle-punched staple fibre supporting scrim	475 (14)	105-150 (140-100)
Typar 3601	non- woven	polypro- pylene	heat-bonded continuous filaments	200 (6)	105 (140)
Mirafi 600X	woven	polypro- pylene	continuous monofilaments	200 (6)	420 (40)
Bidim C-38	non- woven	polyester	needle-punched continuous filaments	340 (10)	150 (100)
Bidim C-34	non- woven	polyester	needle-punched continuous filaments	270 (8)	420 (40)
TrueTex VT-5000	non- woven	polyester	two layer needle-punched staple fibre, resin-dipped on top layer	390 (11)	F38 (F400)
Supac 5P	non- woven	polypro- pylene	needle-punched staple fibre surface, layers are heat-bonded	180 (5)	105* (140)
Typar 3801	non- woven	polypro- pylene	heat-bonded, continuous filaments	270 (8)	n/a*

* Manufacturer's values where available as no samples were tested at Queen's.

(6 in) below the ties, followed by about 90 mm (3.6 in.) of dirty ballast fouled by upward migration of the thin layer of brown sand subballast that was left below the undercutting elevation and by penetration downwards of the cleaned ballast particles. The existing ballast layers were underlain by very dense sand and gravel fouled by black subgrade soil to the bottom of the pit at 600 mm (24 in.). These observations are confirmed by the grading curves shown in Figure 6.3. It is apparent from the profile that the track was undercut to the grey-brown interface clearly evident away from the rail seat area. There has been some mixing at this level between the new and old ballasts, particularly below the rail seat. Degraded grey fines from the Dolomite ballast plus the migrating sand subballast are beginning to foul the lower 50 mm (2 in.) of the replaced ballast layer. The pit was relatively dry. This clearly would be expected to vary depending on the weather and time of year.



geotextile were discoloured in the area below the removed tie at the rail seat by darker fines. There was also a distinct diagonal lineation observed in the ballast profile from a point below the tie and the rail seat out to the end of the tie. The lineation contours conform with the generally estimated zone of influence of stress dissipation which suggests that finer particles have been migrating towards this zone of influence found beneath each rail seat. The geotextile was about 200 mm (8 in.) below the ties. It had been damaged by aggregate abrasion.



When the geotextile was inspected in October at location 4+88.5, the ballast above the geotextile was dirtier and wetter than at the May inspection (4+80.5). The condition of the ballast and geotextile excavated surface is shown in Plate 6.13. The depth to the geotextile was the same as observed for the May excavation (200 mm or 8 in.). The second (October 1981) sample of Typar 3601 inspected, which is shown in Plate 6.14, was visibly more damaged than the first. The ballast below the geotextile was choked with fines. The surface of the fines present at the geotextile-soil interface (below the geotextile) was shiny wet.

During the second visit, the track had noticeably subsided into the ballast through the cut section. A ridge of ballast was forming along the south shoulder of the test track beyond chainage 5+00, as seen in Plate 6.15, and extended to beyond the start of the section containing Bidim C-38 (10+64). It was believed that the failure occurring under the south rail was due to unstable soil conditions which had resulted from water retention caused by the 'plastic-sheet'-like behaviour of the clogged geotextile. The ballast was shifting to the centre of the track and to the outside edge, beyond the ties. The field book in Plate 6.16 illustrates the type of mounding that was occurring along the south shoulder from chainage 5+00 and into the cut section. Plate 6.16, while typical, was taken at approximately chainage 6+00.

6.5.3 Mirafi 600X

The next geotextile installation was Mirafi 600X, installed from chainage 7+27 to 10+64. The track conditions at both of the investigated locations, chainage 7+68 during the May visit and 7+54.5 during the October visit, were very poor. From the cross-sections shown in Figure 6.2, it is evident that the Mirafi 600X was installed at the start of the cut section with exceedingly poor drainage conditions. At the May visit the ballast was badly fouled and a slurry, seen in Plate 6.17, was forming below the geotextile, giving the impression that it was acting as a plastic sheet. The grading curve of the ballast below the geotextile is shown in Figure 6.6. The ballast above the geotextile was similarly fouled, although no sample was taken.

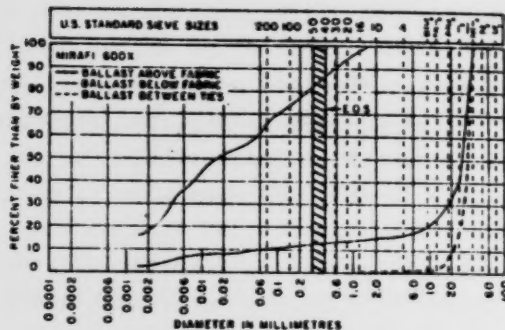


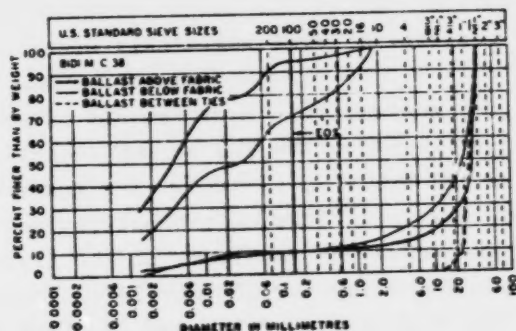
Figure 6.6 Grading curves of ballast samples recovered from Mirafi 600X installation excavated during May 1981 visit

The October visit confirmed that the track structure was badly fouled up to a level between the ties. The fouled condition of the ballast above the geotextile is shown in Plate 6.18. The ballast below the geotextile, shown in Plate 6.19, was similarly fouled. Both the May and October recovered geotextile samples were badly damaged by abrasion and cutting. It was apparent that the geotextile was unable to prevent the fines from rising up into the cleaner ballast. The condition of the geotextile in October is shown in Plate 6.20.

It was apparent by the time of the second visit that the track stability at the geotextile level was slowly worsening. Water had ponded below the rail at the October inspection and fines were caking on both sides of the geotextile. Measurements taken to establish the depth of the geotextile below the tie at the centreline of track and at the south rail, varied by 50 mm (2 in.). The roadbed had been developing a rut under the rail, forcing the ballast below the geotextile to move towards the centre and shoulders of the track. The October pit excavation was extended a further 450 mm (18 in.) below the level of the geotextile. The test pit profile seen in Plate 6.19 clearly showed that the ballast was penetrating down through the unstable subgrade material. The moisture trapped in the track support structure had been maintaining a soft subgrade condition and the water was not noticeably draining through this subgrade. There were a number of isolated spots along this section of track, like the one shown in Plate 6.21, where mud had pumped to the surface beside the ends of the ties. It was clearly obvious that the water was unable to drain away from the structure in this area.

6.5.4 Bidim C-38

The next geotextile, Bidim C-38 (340 g/m² or 10 oz/yd²) was installed from chainage 10+64 to 13+52, and, as depicted from the cross-sections in Figure 6.2, was in a length of track within the cut section. At the May inspection (chainage 11+46), and even more so at the October (chainage 11+41) inspection, the ballast between the ties was starting to foul with dark fine soil particles from the subgrade. At both visits the ballast below the ties was badly fouled and in poor condition. It may be seen from the grading curves in Figure 6.7 of samples taken during the May visit that there was little difference between the gradings of the ballast above and below the geotextile. The ballast in the cribs, however, was still relatively clean. During both visits it was observed that there was standing water located under the rail at the geotextile level, as illustrated in Plate 6.22. Both geotextile samples were found to be completely clogged with soil and saturated with water, as illustrated by Plate 6.23. During the October inspection the depths of the geotextile below the tie at the centreline of track, at the rail, and at the end of the tie were measured as 200 mm (8 in), 225 mm (9 in), and 212 mm (8.5 in), respectively. It was apparent that the roadbed was beginning to rut from the continuous pounding exerted by rail traffic loading on the soaked subgrade.



geotextile under the eastbound track, while the adjacent westbound track prevented drainage on the north side. Small ponds of water were evident on the access road, near the Bidim C-38 locations, and surface water was draining towards the track along the south side of the cut.

6.5.5 Bidim C-34

The next geotextile section contained Bidim C-34 (270 g/m² or 8 oz/ yd²), which is approximately 70 g/m² (2 oz/yd²) lighter than Bidim C-38. This lighter product was located towards the east end of the cut section between chainage 13+52 and 16+43. The profiles shown in Figure 6.2 indicate that there were better relative drainage conditions at the Bidim C-34 installation compared with Bidim C-38. The ballast beneath the ties was dry and in fair condition. There had been some fouling from migration of fines through the geotextile from below and also some degradation of the ballast itself. Ballast under the rail seat was contaminated more than that under the end of the tie. Track conditions observed at the Bidim C-34 installation during the May 1981 visit at chainage 13+65.5 are shown in Plate 6.24. The geotextile was located approximately 200 mm (8 in.) below the tie and was in poor condition. At the rail seat the sample was abraded to the extent that it fell apart under its own weight upon removal from the track. Both the May and October excavations were relatively dry, again attesting to the locally-improved track drainage. No soil samples were taken at this location as space did not permit sampling from all locations.

6.5.6 True Tex VT5000

The True Tex VT5000 geotextile was installed on well-drained fill between chainages 16+43 and 19+14. The May excavation was made at chainage 16+67.5 and the October excavation at chainage 16+80. During the May visit the ballast above the geotextile, as shown in Plate 6.25, appeared dirtier than expected for mechanically-cleaned ballast. It is quite probable that some of the fines were returned to the track with the mechanically-cleaned ballast particles. No doubt a major portion of the fines remaining in the ballast resulted from an incomplete sieving of the ballast from the cut section up track, which would have been exceptionally dirty. A sample of ballast from below the ties was obtained during the May visit and its grading curve is shown in Figure 6.8. The geotextile was located at a depth of 200 mm (8 in.)

below the bottom of the ties. True Tex VT5000 was a unique geotextile insofar as it consisted of two layers, needle-punched together, forming a double thickness below the ties and a single thickness under the shoulders. Samples of geotextile from the centre and shoulder of track were recovered. The grading of the trapped fines removed from the geotextile are shown for the centreline sample in Figure 6.8 and for the shoulder material in Figure 6.9. The general nature of the trapped fines gradation shown in Figure 6.8 for the centreline sample is that of soil trapped in two different 'systems'. Thus there appears a marked change in gradation at about 0.2 mm (No 70 sieve) and again at about 0.04 mm (No 400 sieve), representing 'performance' EOS values of the two separate layers of the geotextile as opposed to laboratory-measured EOS. The value of 0.2 mm (No 70 sieve) corresponds closely with the break in the grading curve on Figure 6.9 for the material across the full width of roadbed supporting the concept that this is the 'performance' EOS of this layer.

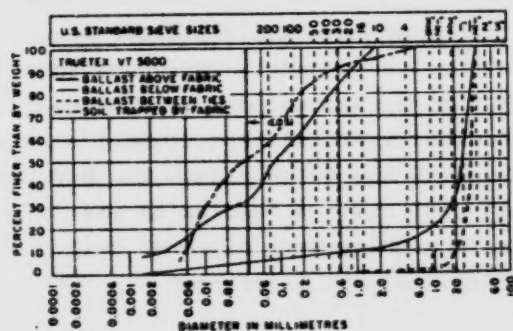
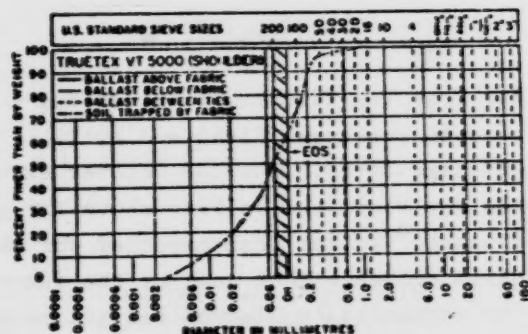


Figure 6.9 ➤

Grading curve of trapped fines removed from the True Tex VT5000 recovered from track shoulder during May 1981 visit

◀ Figure 6.8

Grading curve of ballast samples from rail seat and trapped fines removed from the True Tex VT5000 recovered from track centreline during May 1981 visit



At the October visit the geotextile was also located at about 200 mm (8 in.) below the ties and was dry. Plate 6.26 illustrates the amount of abrasion and puncture wear that the geotextile recovered in October has

experienced in-track, while Plate 6.27 shows the cake formation that has developed beneath the geotextile. The lack of a substantial cake just above the geotextile indicates that there was not a great deal of particle piping and pumping water activity in this section of the test site, although some action obviously has occurred.

During the October inspection the pit excavation at chainage 16+80 was extended a further 300 mm (12 in.) below the geotextile depth. The soil profile, shown in Plates 6.28 and 6.29, revealed a dense filter cake about 50 mm (2 in.) thick beneath the geotextile. The dirty ballast gradually changed to a dark sand and gravel at the bottom of the pit. The dark soil at the bottom of the excavated pit was consistent with the other deep profiles, including the control site.

6.5.7 Supac 5P

Supac 5P was installed from chainage 19+14 to 21+17 on fill. The cross sections shown in Figure 6.2 clearly indicate the increased elevation of the track at the end of the test section. The ballast above the geotextile was dry but contained an observable amount of dark fines, as noted in Plate 6.30. The profile was cleaner at the shoulder than under the rail. The condition of the ballast below the rail seat was confirmed by the grading curves shown in Figure 6.10, which indicated that little prevention of fouling by the geotextile had occurred in the ballast above the geotextile, no doubt due to its damaged condition. The geotextile was approximately 150 mm (6 in.) below the ties during the May inspection at chainage 19+36.75, and 200 mm (8 in.) below the ties during the October inspection at chainage 19+47. The geotextile samples appeared damaged to about the same extent as the Terrafix 370RS samples, with numerous small punctures and abrasions occurring at the rail seat, as shown in Plate 6.31. The fouled ballast beneath the geotextile was moist but not cemented. There did not appear to have been excessive pumping or particle movement in this area of the track since the rehabilitation, although the dark, dry subgrade fines found in the ballast indicated that some pumping had occurred. The improved local drainage conditions were sufficient to have resulted in a stable track condition.

control section had cleaner ballast above the geotextile level, as seen by comparing Figures 6.3 and 6.4. This suggests that even the badly-abraded light/mediumweight geotextiles have contributed over the short term to greater track stability. Indeed, had the control site been located across the swamp, a different track condition would have been observed, unquestionably requiring a geotextile.

Another portion of track without geotextile, given a surficial inspection only, was that west of the access road at MP155. Its location is shown in Figure 6.1. A general view of the area is shown in Plate 6.36. This was undercut at the same time as the track for the main test section and, after 24 months, requires undercutting again to remove the numerous pumping track sections typically illustrated in Plate 6.37. It is apparent that adequate drainage was not provided for the track through this cut section and the subgrade is softening and piping due to the constant presence of moisture in the track structure, as seen in Plates 6.38 and 6.39. Once the subgrade piped into the track, the ties lost their support from the ballast, resulting in both subsidence and running rail. Clearly, from a comparison of the performance of the two cut sections, use of geotextiles in track not subject to any drainage improvement will retard fouling; however, it is clearly poor engineering to use them as a substitute for drainage improvement.

6.7 OVERALL PERFORMANCE

The test site illustrates that track performance is very much a function of local drainage or lack of drainage. It therefore became obvious that drainage affected the performance of each geotextile location. The fill sections were better drained and had less track instability and pumping. The cut section, located in the central portion of the test site, exhibited very poor drainage conditions and therefore greater instability. The geotextiles performed a function of imperfect separation and, where capable, some improvement in track drainage.

The needle-punched, staple-fibre, non-woven polyesters and polypropylene geotextiles (Terrafix 370RS, True Tex VT5000 and Supac 5P) appeared to perform reasonably in their respective test sections. The ballast above each geotextile was dry relative to the other sites. Moisture was present below the geotextiles but they appeared to be

providing some lateral drainage to the shoulders. There was reasonable retention of the fines below each geotextile, although had more water been present a different conclusion would no doubt have been required. The needle-punched, staple-fibre geotextiles did not appear to be damaged as much as the geotextiles of other manufacture, probably due to a better drained section and thus less track movements. The synthetic binder on the top surface of the True Tex VT5000 product appeared to have better protected the individual fibres from ballast abrasion than that of the other geotextiles.

The two needle-punched, continuous-filament, non-woven geotextiles (Bidim C-34 and C-38) were extremely degraded by their track conditions. The open-fibre structure, believed due to insufficient needle-punching during manufacture, allowed for easy penetration of fine soil particles. These silt and fine sand grains either passed through the geotextile to foul the new ballast or became trapped within the geotextile, reducing substantially its permeability. Trapped particles further abraded the geotextile internally. The Bidim C-34 abraded to a shredded condition. The Bidim C-38 sample was entirely clogged with fine soil particles after 18 months.

The thinner, lightweight to mediumweight geotextiles were found to be unsuitable for track rehabilitation applications. In fact, they created problems. Typar 3601 and Mirafi 600X were in a poorly drained track section. Their inability to permeate excess water from the structure intensified track instability. The spun or heat-bonded geotextile similarly clogged within a short period of time and acted as a non-permeable membrane by developing slick films of wet, slippery soil on both sides of the thin geotextile material. Installation of these geotextiles may create unnecessary slippage or instability in the trackbed. Extensive overlap of geotextiles may create similar failure sliding planes. Lateral movement of this nature was documented at the test site in Caldwell, Texas, by Barnett and Newby (1980).

In summary, the needle-punched, staple-fibre geotextiles performed reasonably, but were in a track environment (fill section) which did not offer extreme test conditions. None of the lightweight or mediumweight geotextiles at Loudonville would be expected to perform adequately in track sections with a high water table such as swampy terrain. Furthermore, geotextiles, while clearly valuable in retarding

fouling and thus reducing maintenance, should never be used as a substitute for drainage improvement.

6.8 LATERAL PERMEABILITY TESTS

Most of the geotextile samples obtained from track were too degraded to test for lateral permeability. Only two samples of True Tex VT5000 were undamaged enough to produce two permeability test samples. The results for these two samples are shown in Figures 6.12 and 6.13 and are from the centreline and shoulder respectively. The permeability testing was similar to that done on the CN-recovered geotextiles. The centreline material is made up of two layers needle-punched together; an undipped polyester layer extending the full width of the track, and the other resin-dipped polyester layer with an extremely low EOS added under the traffic area only. It may be seen that this low EOS material

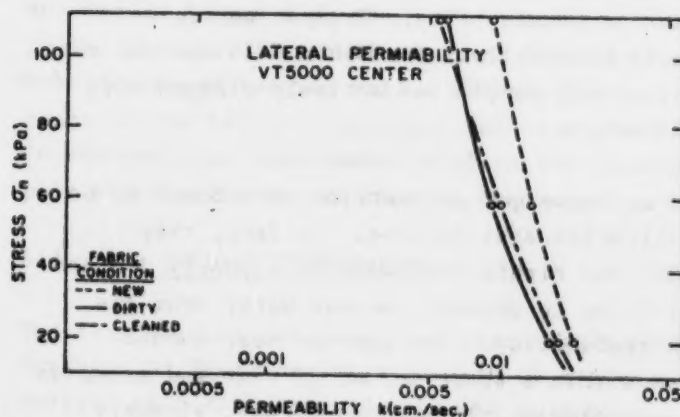
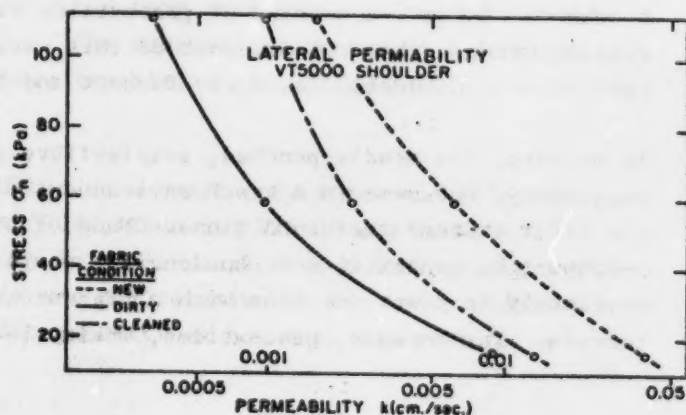


Figure 6.12

Lateral permeability of as-recovered, cleaned and new True Tex VT5000 geotextile from two-layered centreline material

Figure 6.13

Lateral permeability of as-recovered, cleaned and new True Tex VT5000 geotextile from single-layered shoulder



exhibited very little fouling and retained its permeability exceedingly well. The single-layer shoulder material, while subject to less pumping, had a much higher EOS and showed more clogging with loss of permeability. Note that both these geotextiles have much smaller EOS values than the Terrafix materials from the CN investigations. This results in smaller virgin permeabilities. Thus there is one order of magnitude decrease in scale in Figures 6.12 and 6.13 compared with the values from the CN installations.

6.9 OVEN-DRYING OF GEOTEXTILES

Small samples of all geotextiles recovered from the field were subject to oven-drying at 105°C (212°F). All the non-polyester geotextiles from Loudonville became brittle and were unusable. While such temperatures are not likely to occur in the field, the results suggest that some instability has occurred to the non-polyester polymer geotextiles. Further work clearly needs to be done on the long-term environmental effects on polymers used in geotextiles for track rehabilitation.



Plate 6.1 View of south track looking westward away from geotextile installation, showing approach embankment (foreground) and cut section (background) undercut at same time as geotextile installation section



Plate 6.2 View of south track looking westward, taken from ditch at same chainage as Plate 6.1



Plate 6.3 View of south track looking eastward along section containing geotextiles, taken from same chainage as plates 6.1 and 6.2



Plate 6.4 View of south track looking eastward, taken from ditch at same chainage as Plate 6.3

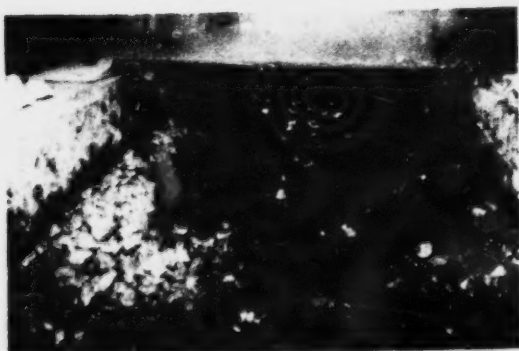


Plate 6.5 General view of test pit excavation of control site at 1+44 just prior to start of geotextile test installations

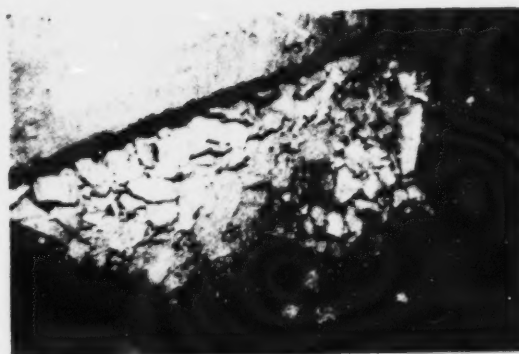


Plate 6.6 From centreline of track showing upward migration of what remains of sand subballast and upward migration of dark subgrade soil

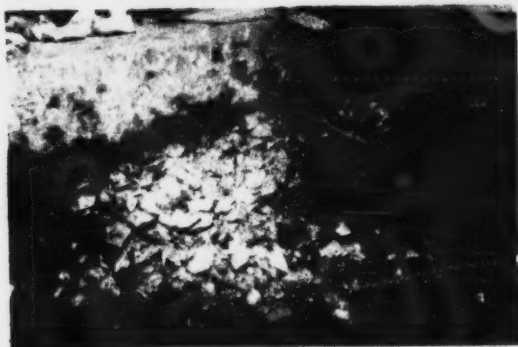


Plate 6.7 View of west wall below rail seat of control site test pit taken from centreline of track

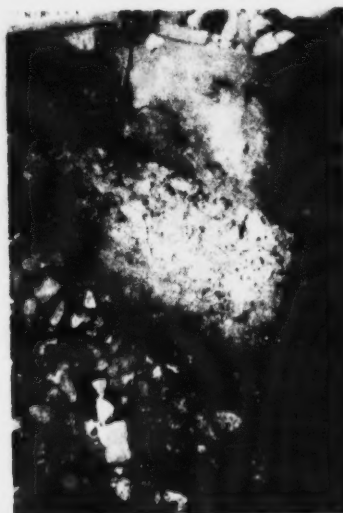


Plate 6.8

View of west wall below rail seat of control site test pit taken from shoulder of track



Plate 6.9 Condition of west wall, geotextile and ballast below geotextile during May 1981 excavation of Terrafix 370RS at 1+76.5

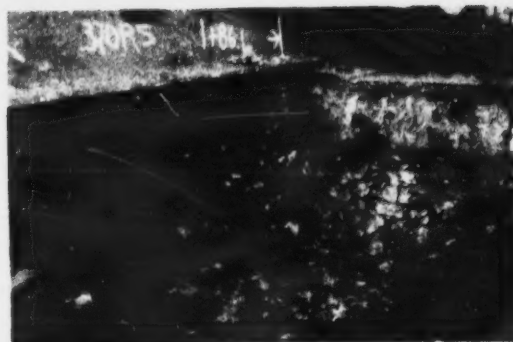


Plate 6.10 General view of east wall below rail seat and end of tie during October 1981 excavation of Terrafix 370RS at 1+86.1

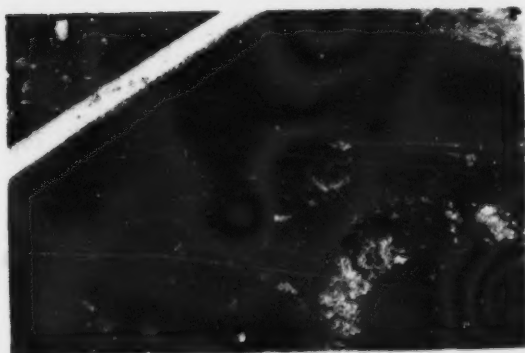


Plate 6.11 Condition of geotextile and ballast below geotextile during October 1981 excavation of Terrafix 370RS

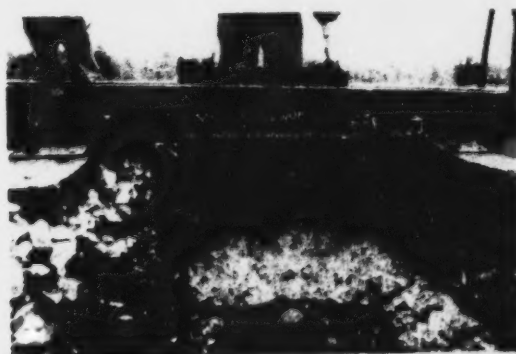


Plate 6.12 Visual condition of terrafix 370RS from excavation made October 1981

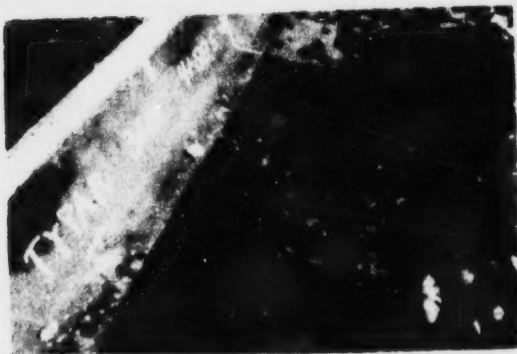


Plate 6.13 Condition of east wall below rail seat and end of tie during October 1981 excavation of Typar 3601 at 4+88.5



Plate 6.14 Condition of Typar 3601 below rail seat during October 1981 excavation



Plate 6.15 Surficial subsidence evident during October 1981 visit as a track entered and went through cut section. Personnel in background are at Mirafi 600X location 7+54.5

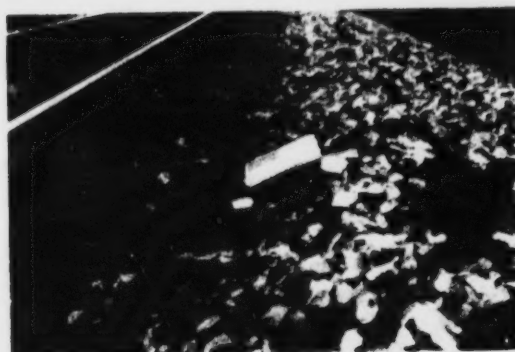


Plate 6.16 Close up to surficial subsidence evident during October 1981 visit at approximately 6+00

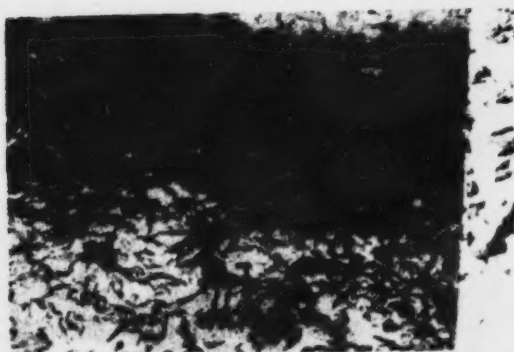


Plate 6.17 Slurried fines observed below monofilament woven Mirafi 600X during May 1981 visit



Plate 6.18 Condition of east wall and subsidence observed at the geotextile elevation showing water trapped within the roadbed at the October 1981 excavation of Mirafi 600X



Plate 6.19 Condition on wall excavated 300 mm (12 in) below Mirafi 600X elevation showing no subballast and very bad fouling by subgrade during October 1981 visit



Plate 6.20 Condition of geotextile Mirafi 600X observed during October 1981 visit

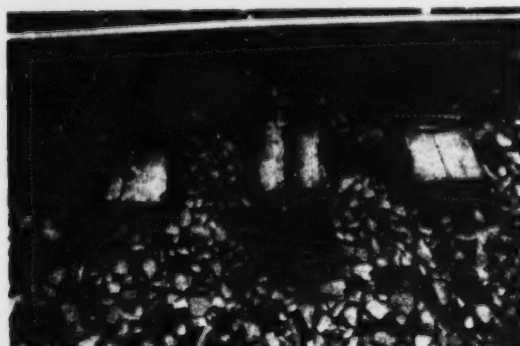


Plate 6.21 Signs of pumping occurring at surface of track during October 1981 visit near Chainage 9+00 above installed Mirafi 600X

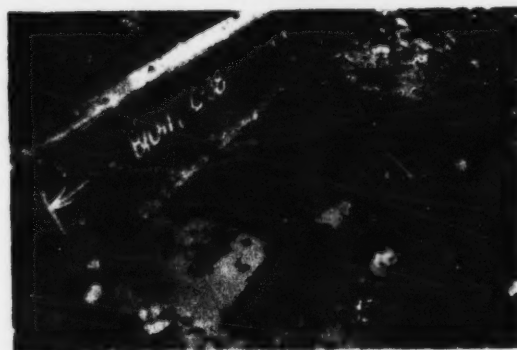


Plate 6.22 Condition of east wall and subsidence observed at the geotextile elevation showing water trapped within the roadbed at the October 1981 excavation of Bidim C-38

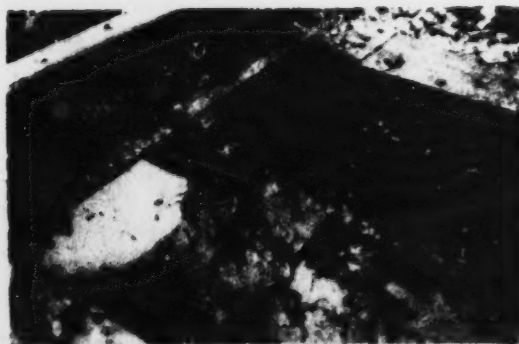


Plate 6.23 Condition of geotextile Bidim C-38 observed during October 1981 visit

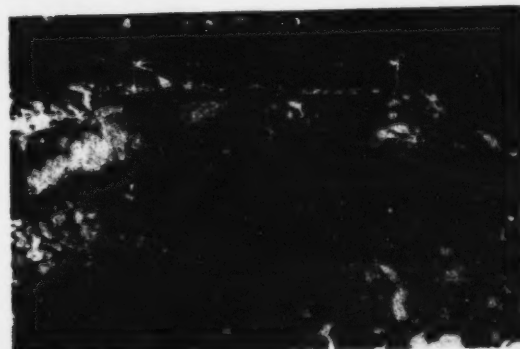


Plate 6.24 Condition of west wall and relatively dry geotextile elevation observed at May 1981 excavation of Bidim C-38

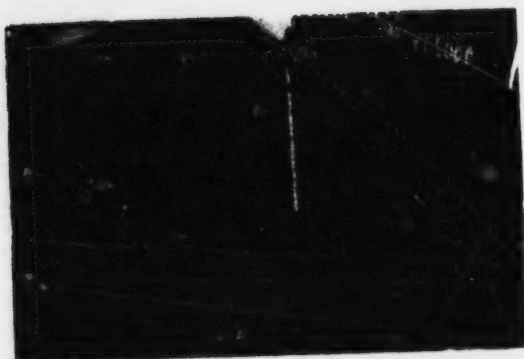


Plate 6.25 Condition of west wall and ballast below geotextile during May 1981 excavation of True Tex VT5000

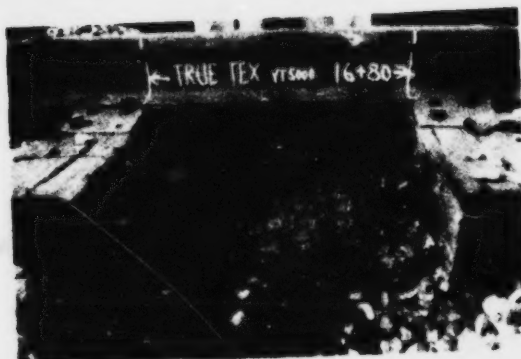


Plate 6.26 Condition of geotextile True Tex VT5000 observed at October 1981 visit



Plate 6.27 Partially-stained condition of lower surface and cake formation below True Tex VT5000 observed at October 1981 visit



Plate 6.28 Condition of east wall of excavation extended below ties during October 1981 inspection of VT5000 installation



Plate 6.29 Sand subballast cake formation below VT5000 observed during October 1981 visit

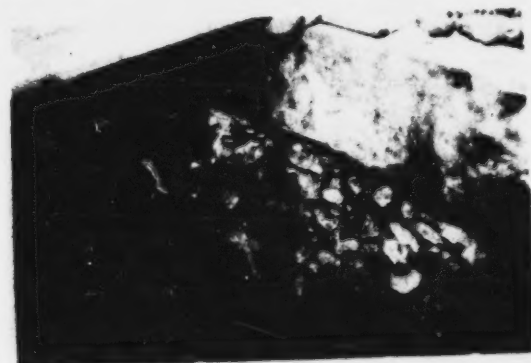


Plate 6.30 Condition of west wall above Supac SP taken from track centreline during October 1981 visit

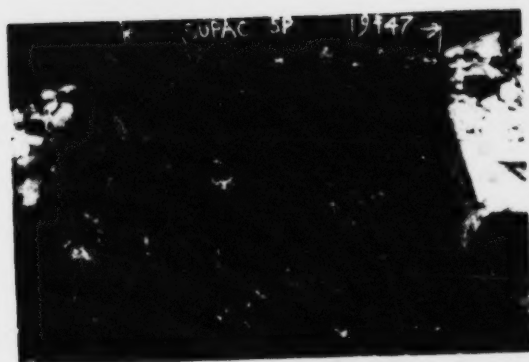


Plate 6.31 Condition of geotextile Supac 5P and underlying ballast observed during October 1981 visit

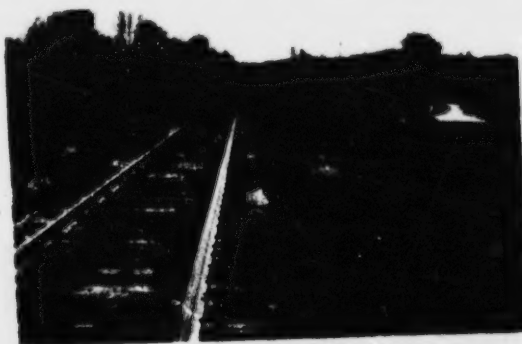


Plate 6.32 Condition of westbound track which did not contain geotextiles and was not subject to undercutting in November 1979, observed during May 1981 visit

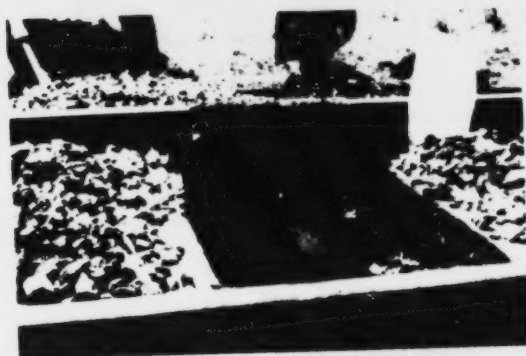


Plate 6.33 Condition of geotextile Typar 3801 observed during May 1981 visit

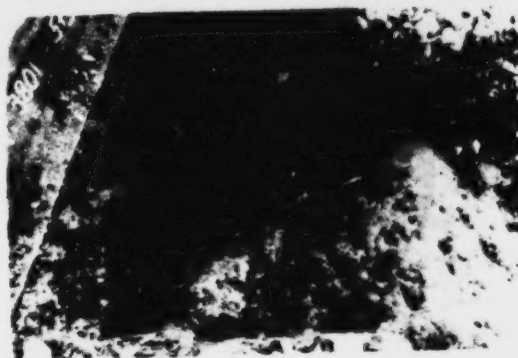


Plate 6.34 Wet condition of fouled ballast and geotextile Typar 3801 at geotextile elevation during October 1981 visit

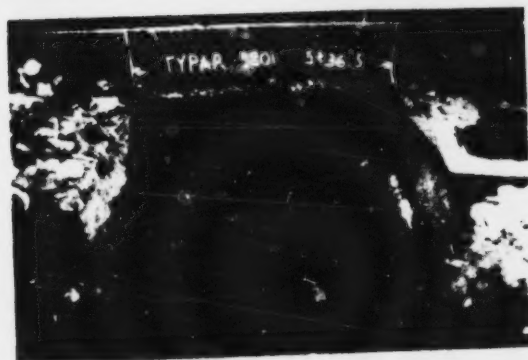


Plate 6.35 Condition of east wall showing dirty wet ballast below rail seat and subsidence below track at geotextile elevation during excavation of Typar 3801, October 1981



Plate 6.36 General view of drainage and south track surface conditions through cut situated immediately west of main test area at MP155, observed October 1981



Plate 6.37 Pumping track surface of south track west of MP155 undercut October 1979 at same time as geotextiles were installed in section just east of MP155, observed October 1981

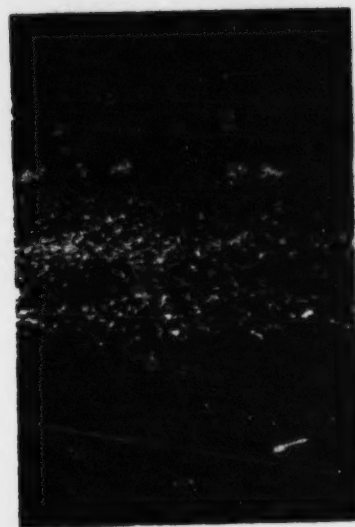


Plate 6.38 Close-up of typical pumping seen in Plate 6.37, also showing shallow drainage ditch, observed October 1981

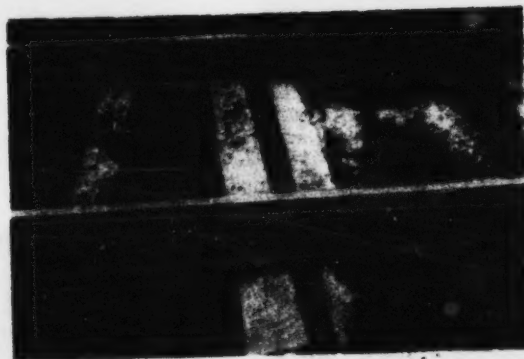


Plate 6.39 Particularly bad pumping track seen on south track viewed in Plate 6.37, observed October 1981

CHAPTER 7

ASSESSMENT OF CONRAIL'S SALEM TEST

7.1 INTRODUCTION

The Loudonville test allowed assessment of the performance of light-weight and mediumweight geotextiles. At Salem, five of the six geotextiles were over 500 g/m² (14 oz/yd²) in weight and the test site afforded an assessment of the performance of the heaviest-available geotextiles at the time of installation. The visits took place the day after each of the Loudonville visits, on May 21, 1981, and again on October 8, 1981, some six and eleven months after installation, which was in November 1980. The geotextile test site was located in the town of Salem, Ohio, just west of the grade-crossing at Elsworth Street, on the westbound mainline track. The method of inspection was similar to that performed at the Loudonville site.

7.2 GENERAL DETAILS

The Salem test track was over nearly-flat terrain with poorly drained soils. The track structure was similar to that at Loudonville, with 70 kg/m (140 lb/yd), continuous-welded rail on wooden ties placed at 500 mm (20 in.) spacings. A major difference in the rehabilitated track was that the Dolomite replacement ballast above the geotextile was new, as opposed to 'cleaned' at Loudonville. Laboratory tests indicated that the ballast was comparable to our class D ballast, with a combined Mill and Los Angeles Abrasion value of 64 per cent. There were approximately 200 mm (8 in.) of ballast between the bottom of the ties and the typical local ground elevation. Shoulder ditches were not present, but there were a number of concrete slabs spaced along and beside the track structure which suggested that there may be underground conduits or drain pipes below the surface. The estimated annual traffic was about 23 million gross tonnes (25 MMGT) per year, similar to the Loudonville test site.

Six types of geotextiles were installed on the westbound mainline track at the Salem test site. They are listed along with a general description of their physical properties in Table 7.1. The geotextiles were

TABLE 7.1

SOME PROPERTIES OF GEOTEXTILES IN-TRACK AT SALEM, OHIO

Product	Type	Fabric	Description	Weight g/m ² (oz/yd ²)	EOS mm (No)
Fibretext C.Z. 300	non- woven	polypro- pylene	needle-punched continuous filaments, surface layers are heat-bonded	300 (9)	210-300 (70-50)
Bidim C-42	non- woven	polyester	needle-punched continuous filament	540 (16)	105 (140)
True Temper 700	non- woven	polyester	needle-punched staple fibre	700 (20)	40 (400)
Terrafix 814B	non- woven	polypro- pylene, polyester	two layers, each needle- punched staple fibre, needle- punched together	814 (24)	40 (400)
True Temper 900	non- woven	polyester	needle-punched staple fibre	900 (26)	40 (400)
Terrafix 400NR	non- woven	polyamide	needle-punched staple fibre supporting scrim, resin- dipped	550 (16)	210 (70)

cut to approximately 8 m (25 ft) lengths to form six repetitive groups of six geotextile types. The starting point of the test site was opposite the corner of the concrete crossing gate foundation northwest of the tracks. The total length of the test site was 287 m (940.5 ft). The shorter distance between sampling locations was intended to establish uniform track conditions. The sets of test samples taken at

the six-month and twelve-month inspections were taken from the first group of geotextiles, between chainages 1+10 and 2+50, in the section of track illustrated in Plate 7.1.

7.3 CONTROL SITE WITHOUT GEOTEXTILES

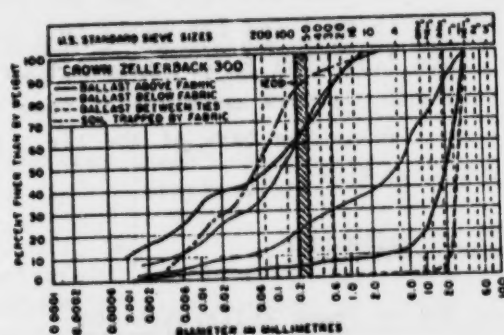
A control site without geotextile was established, at the request of the writers during the second visit, at chainage 0+81.5. The test pit, shown in Plate 7.2, was relatively dry compared to the sampling locations further west. The ballast found directly below the removed tie was fouled with small grey particles degraded from the ballast and dark-grey fines that had migrated towards the surface from the subgrade. Mixing between the ballast layer and the dirty subballast was noticed between 125 mm (5 in.) and 175 mm (7 in.) below the base of the tie, as shown in Plate 7.3. The fouled material became very dense at about 225 mm (9 in.) and the dark colour continued to the bottom of the pit at 300 mm (12 in.) below the base of the tie. No ballast samples were recovered from this site.

7.4 GEOTEXTILES INSTALLED

7.4.1 Fibretext 300 or Crown Zellerbach 300

The first geotextile installed was Fibretext 300, placed between chainages 1+09.2 and 1+38.5. This geotextile, referred to as Crown Zellerbach 300 in the Conrail test program, weighing 300 g/m² (9 oz/yd²), was the lightest geotextile of the six, being some 240 g/m² (7 oz/yd²) lighter than any of the other geotextiles installed at Salem. The ballast below the tie was fouled at both the six-month and twelve-month inspections to the same degree as the control site. The geotextile functioned very poorly. It was not retaining the dark subgrade fines, as evident from the grading curves of samples taken at six months, shown in Figure 7.1. The recorded depths of the two geotextile samples recovered at six and eleven months were 162 mm (6-1/2 in.) and 150 mm (6 in.) below the tie, and were located at chainages 1+16.7 and 1+21, respectively. Both samples were severely torn on either side of the area below the rail seat, as illustrated by the six-month sample shown in Plate 7.4. It is apparent that the tamper tines agitated the ballast particles sufficiently to completely degrade the geotextile during the tamping process. The geotextiles were also badly abraded

below the bearing area of the removed tie. On removal of the geotextiles it was apparent that the fouled ballast below the geotextile was cemented by fines which were temporarily dried in situ. Both locations were relatively dry at the time of the visits, although clearly when the track retained water piping of fines had occurred. During the first visit a small sample of geotextile was removed from the centre of track and the grading curve of the trapped fines removed from that sample is shown in Figure 7.1. Particles greater than the EOS of the geotextile are clearly evident, suggesting that the geotextile is not of sufficiently tight construction to resist penetrating sand and silt sizes.



rail seat. Both geotextile samples were located about 200 mm (8 in.) below the bottom of the tie. The increased depth appeared to have helped protect the geotextile against excessive wear during tamping, although there was some abrasion damage showing on both samples. Small holes were located in the area below the rail seat. The ballast below the geotextile was fouled. The geotextile was preventing a great deal of fine soil from piping, but the 75 mm (3 in.) of fouled ballast above the geotextile indicated that the geotextile was too porous. As noted, the site was poorly drained so that, during wet weather, fine soil had passed through the geotextile, pumped with the moisture from below, and had collected at the free water surface above the geotextile.

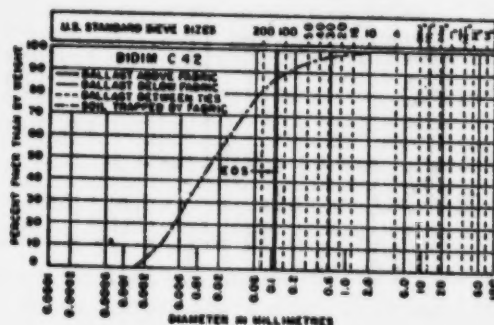


Figure 7.2 Grading curve of trapped fines removed from geotextile Bidim C-42 recovered during May 1981 visit

7.4.3 True Temper 700

The next geotextile installation was True Temper 700 at chainages 1+70 and 1+74.5. A grading curve of trapped fines from a small sample of geotextile taken from the centreline of track during the May visit is shown in Figure 7.3. The ballast above the geotextile was relatively clean at both locations, but some migration of dark fines was apparent above the damaged area of the geotextile as shown in Plate 7.6, recorded at twelve months. The depth between the ties and the geotextile samples varied between 135 mm (5.5 in.) and 150 mm (6 in.). The geotextile/ballast interface was more irregular than normal. Plate 7.7 illustrates the condition of both the geotextile and the prepared ballast surface. It shows the irregular surface produced by the

ballast tamper due to insufficiently deep geotextile installation. A number of holes in the geotextile may be seen, which can be attributed to a combination of the irregular surface and the tamping of the track. Under the circumstances, the geotextile performed well. The fibres elongated around most of the irregularities and there was no apparent major abrasive damage from in-service traffic wear, even though the geotextile was close to the base of the ties. Most of the minor abrasive damage occurred under the rail seat of the removed tie. The sample taken after twelve months in service was stiff and heavy from fine soil particles which had been forced into the geotextile by the repetitive traffic loading.

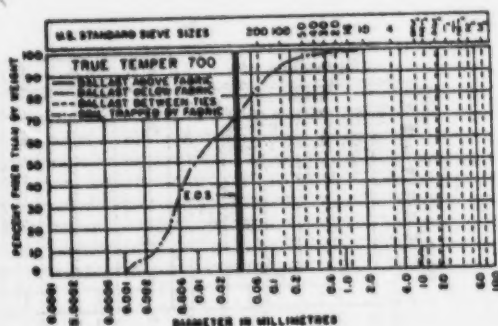


Figure 7.3 Grading curve of trapped fines removed from geotextile True Temper 700 recovered during May 1981 visit

7.4.4 Terrafix 814B

The two test locations for Terrafix 814B were at chainages 1+95 and 1+92.5. The ballast profile observed during the October visit is shown in Plate 7.8 and a grading curve of the trapped fines from a small centreline sample of geotextile recovered during the May visit is shown in Figure 7.4. The ballast above the geotextile was in relatively good condition at both locations, as illustrated by the profile view in Plate 7.8. The depth between the bottom of the ties and the geotextile was 150 mm (6 in.) at the six-month inspection and from 125 to 160 mm (5 to 6 in.) at the twelve-month inspection. Both samples experienced tamper damage similar to that shown in Plate 7.9. Most of the damage occurred in the shallow areas of the installation. The ballast below the geotextile was completely fouled with fine soil particles.

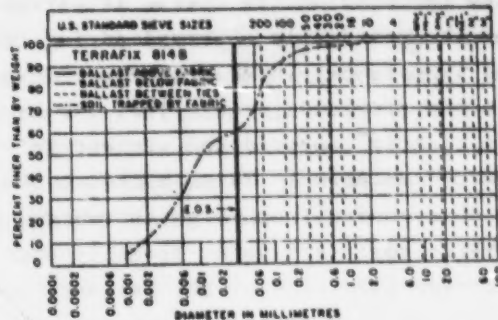


Figure 7.4 Grading curve of trapped fines removed from geotextile Terrafix 814B recovered during May 1981 visit

Examination of the grading curve of the trapped fines in the geotextile sample (Figure 7.4) shows that the soil has been trapped in two different 'systems', reflecting the two-layered nature of the geotextile. Thus there appears a marked change in the gradation at about 0.1 mm (No. 140 sieve) and again at about 0.015 mm (No. 400 sieve), representing 'performance' EOS values of the two separate layers of the geotextile as opposed to laboratory-measured EOS. The measured laboratory value of the EOS shown on Figure 7.4 is 0.04 mm (No. 400 sieve) but as recorded in Table 7.1, the EOS is, in fact, less than this value. The exact laboratory value is unknown since the value of 0.04 mm (No. 400 sieve) is the lowest value presently measurable and this size of particle failed to pass through the geotextile during the laboratory test. Thus the lower 'performance' value recorded from the field is quite reasonable.

7.4.5 True Temper 900

True Temper 900 was the next geotextile to be examined. The test inspections were at chainages 2+05 and 2+08. The ballast profile observed during the October visit is shown in Plate 7.10, and a grading curve of the trapped fines from a small centreline sample of geotextile recovered during the May visit is shown in Figure 7.5. The ballast above the geotextile was in relatively good condition but fouling was evident below the rail seat, as seen in Plate 7.10. There was some degradation of the ballast and some fines had migrated up through the damaged areas of the geotextile from below it. The ballast was moist

at the time of the two visits. Both geotextile samples were located 150 mm (6 in.) below the base of the ties. Illustrated in Plate 7.11 is the condition of the geotextile observed during the October visit, showing a few holes from tamper-induced damage. These were not as numerous as seen in the previous geotextiles. The heavier weight of the True Temper 900 has clearly improved the geotextile's resistance to ballast penetration and abrasion. This thicker geotextile was installed adjacent to a roof without a gutter which, during heavy rainstorms, could discharge roof rain water directly onto or close to the track. The moist-to-wet condition of the ballast profile is illustrated by Plate 7.10. In this poor drainage environment the geotextile was susceptible to more clogging than the geotextiles to the west.

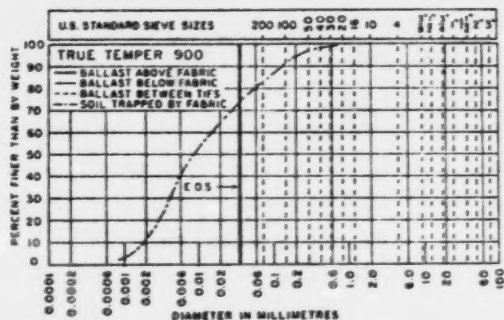


Figure 7.5 Grading curve of trapped fines removed from geotextile True Temper 900 recovered during May 1981 visit

7.4.6 Terrafix 400NR

The final geotextile inspected was Terrafix 400NR at chainages 2+20.25 and 2+45.5. Both samples were located adjacent to the area receiving roof runoff. The ballast at both locations was relatively clean but damp, with some degraded ballast fines having been washed down to the geotextile. There was a small trace of dark subgrade fines observable above the geotextile during the October inspection. The geotextile, during both inspections, was found to be wet and appeared to be clogged with fine soil particles. This was in part due to the high EOS of this geotextile, with the result that the grading curve of the trapped particles, shown in Figure 7.6, was much coarser than those of the

other geotextiles. It may be seen that 40 per cent of the trapped material is retained on the 74 micron sieve (No. 200) compared with 20 per cent for the other four heavyweight geotextiles. Also shown in Figure 7.6 are grading curves of the ballast above and below the geotextile. The ballast above the geotextile may be seen to be relatively void of fines, confirming visual observations. The geotextile depth below the base of the tie was 125 mm (5 in.) at the May location and 150 mm (6 in.) at the October location.

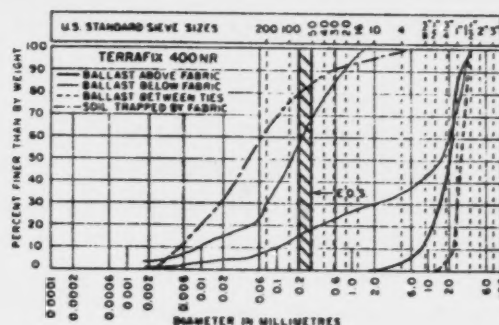


Figure 7.6 Grading curve of trapped fines removed from geotextile Terrafix 400NR and ballast samples recovered during May 1981 visit

The October sample was in worse condition than the May sample, but again the majority of the damage could be related to the tamping forces at the time of installation. Plate 7.12 shows the damage to the geotextile caused by the tamper tines and abrasive damage caused by the aggregate movements. Most of the damage has occurred beneath and close to the rail. There was no immediately-noticeable abrasive damage to the geotextile outside the tamping area of the track on either sample. It is believed this was due to the synthetic-resin coating which contributed to the preservation of the individual fibers. Plate 7.13 illustrates the harsh environment created by the tampers when insufficient ballast cover has been placed on the geotextile prior to the initial tamping activity. Also apparent from Plate 7.13 is the fact that the dirty ballast below the geotextile was completely clogged with fine soil particles.

The overall performance of the geotextiles at the Salem test site was affected by their shallow depth of installation. Five of the six geotextiles were excavated from a depth of 150 mm (6 in.) or less below the bottom of the ties. This depth was clearly not sufficient, as demonstrated by the numerous geotextile samples that had large, totally-degraded areas beneath the rail where the ballast had been agitated by the track vibratory compaction equipment. In many of the inspection pits, the geotextiles were found to have been damaged by excessive ballast movement. The dirty ballast surfaces below the geotextiles at those locations were particularly irregular due to tamper activity.

The test site was visited too early to observe excessive abrasion of the heavier geotextiles away from the tamped area of track, but there was a considerable amount of observable abrasion already occurring with the low-density-of-needling, continuous-filament geotextiles. The thick geotextiles with high-density-of-needling staple fibres were elongating very well over the irregular ballast edges without any obvious increase in EOS. Resin-dipping of the staple fibres increased the abrasion resistance of the geotextile, resulting in a better performance against abrasion than the heavier, non-resin-dipped, staple-fibre geotextiles.

A comparison of the grading curves of trapped fines in the heavy geotextiles, Figures 7.2 to 7.6, indicates the importance of having a low EOS for a track rehabilitation geotextile. The low EOS is important to prevent internal clogging, maintain lateral permeability for drainage, and avoid internal abrasion of the geotextile by intruding particles.

Plate 7.14 illustrates the local ditch drainage conditions at this test site. The drainage at the Salem test site is considered inadequate for longevity of the ballast-cleaning operation, as shown by the ballast conditions observed during the second field visit. The ballast was beginning to clog with fine soil particles just above the geotextile at many of the test locations. Unfortunately, the geotextiles were installed below the local ground elevation. This has prevented proper drainage of water by the geotextile away from the load-bearing area of the subgrade. With time, the ballast above the geotextile will become

fouled either by migration of fines through the geotextile and its abraded areas or from the fines in the shoulders located above the geotextile which will be washed into the track area. In the short term, however, the geotextiles have reduced the amount of particle mixing between the new and existing ballast layers.

Poor drainage at this test site was further complicated by a station house located near the track shoulder which discharged roof rain water directly on the track over part of the test section. Another complicating factor was a concrete slab behind the pulled tie, as seen on Plate 7.14, which suggested the presence of a conduit trench that would facilitate the lowering of any high seasonal ground water table.

The effect of the station house runoff water was apparent during the inspection. The track next to the building was observed to be significantly wetter than the rest of the track. The resultant effect was a softer subgrade which increased the chance of geotextile clogging and fouling of the ballast above the geotextile.

Clearly, drainage improvement must be an integral part of any track rehabilitation, with or without geotextiles, by ditching next to the shoulders or by installing subsurface drains. Any of these methods, properly undertaken, would improve lateral drainage capability, thus progressively improving and maintaining the track structure. Even the subgrade could be expected to improve at some sites as surficial infiltration would be reduced or prevented.

7.6 PERMEABILITY TEST RESULTS

The results of permeability tests, done in the same manner as for the CN test installation, on the samples recovered from the centre of track during the May 1981 visit are shown in Figure 7.7. Since the geotextile had only been in track for about half a year, a great degree of fouling, and thus reduction of permeability, was not to be expected. This was not confirmed by the tests on Terrafix 400NR and True Temper 900 specimens which were both subject to roof runoff. Thus, again the comparison of geotextile performance was complicated by the drainage and environmental impact of the individual installations. The above two geotextiles were subjected to a greater degree of fouling due to the substantially-wetter sustained conditions.

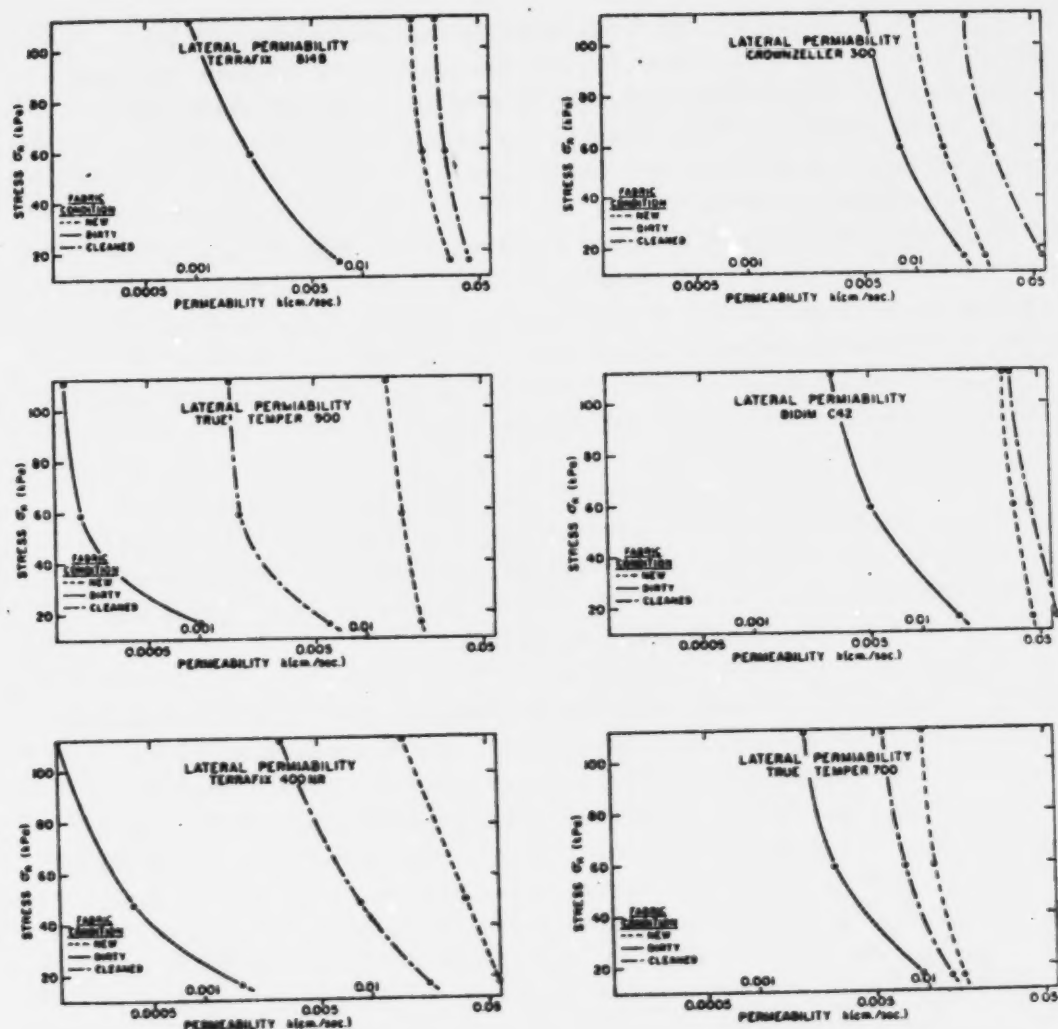


Figure 7.7 Permeability test results on geotextile samples recovered from centre of track during May 1981 visit

Even in this fouled condition, the geotextiles had permeabilities over 10^{-6} m/sec (100 ft/year), which, while not good, is typical of fine sand and inorganic silt. Had these geotextiles been laid with a slope towards the ditch and the ditch invert been lower than the geotextile elevation, longevity of the geotextile permeability might have been enhanced.

Since such was not the case, these geotextiles can be expected to deteriorate and the track foul much quicker than generally acceptable. With good drainage, a ballast life from breakdown only could reasonably be expected to be 1,000 million gross tonnes (1.1 MMGT) or about 40 years between undercutting cycles. Fouling from pumping, wind-blown sources, etc., would, of course, reduce this. Even longer life would be expected for better-quality ballast not subject to fouling. Ideally, the geotextile should maintain an adequate permeability to function in the track, at least for the normal ballast maintenance period of say 10-12 years.



Plate 7.1 Conrail's geotextile test site at Salem, Ohio, looking westward, showing drainage ditch, closeness of excavated ties and Elsworth Street grade crossing in background

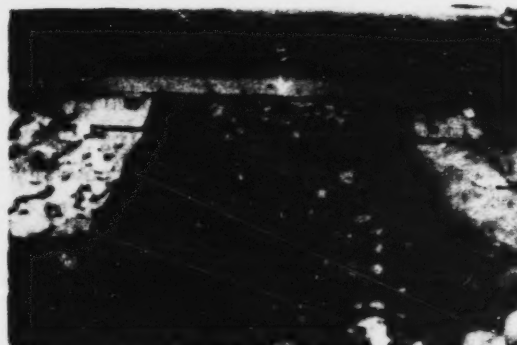


Plate 7.2 Condition of ballast next to rail seat at control site without geotextile during October 1981 visit

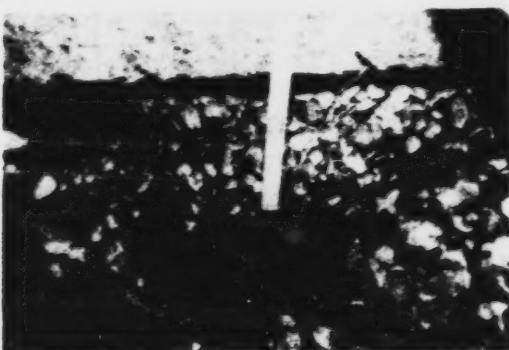


Plate 7.3 Close-up of west wall of control site excavation, showing undercutting demarcation between old dirty ballast and new make-up ballast with some fouling of new ballast evident, observed October 1981



Plate 7.4 Damage of geotextile due to tamper tines agitating ballast which abraded geotextile Fibertex 300, observed during May 1981 visit



Plate 7.5 Retention of fouled ballast fines by Bidim C-42 and fouling below rail seat above damaged geotextile, observed on west wall of excavation made during October 1981 visit



Plate 7.6 Condition of west wall of excavation above True Temper 700, also showing abraded geotextile damage from tamper-agitated ballast particles observed during October 1981 visit



Plate 7.7 Abrasion and elongation of geotextile True Temper 700 caused by ballast tamping observed during May 1981 visit

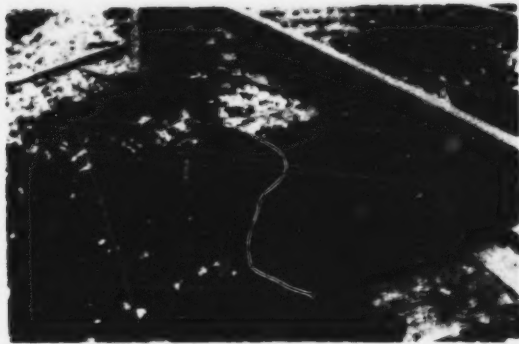


Plate 7.8 Condition of west wall of excavation above Terrafix 814B, also showing fines retained by geotextile, observed during October 1981 visit

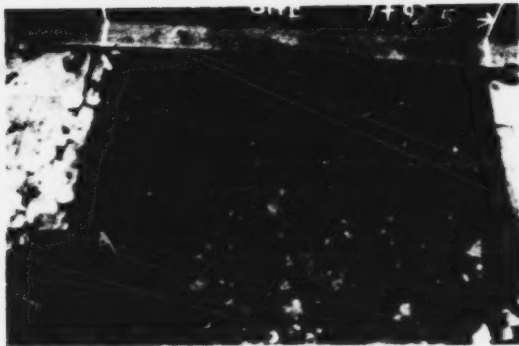


Plate 7.9 Abrasion of geotextile Terrafix 814B caused by tamper agitation of ballast particles, observed during October 1981

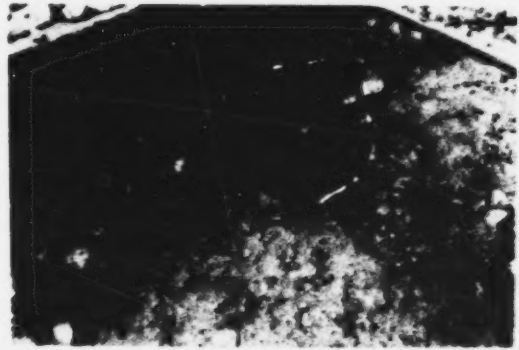


Plate 7.10 Moist condition of excavation above True Temper 900 as observed during October 1981 visit

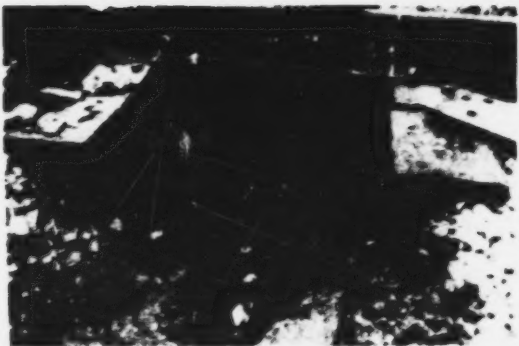


Plate 7.11 Condition of geotextile True Temper 900 showing small abrasion/puncture holes observed during October 1981 visit

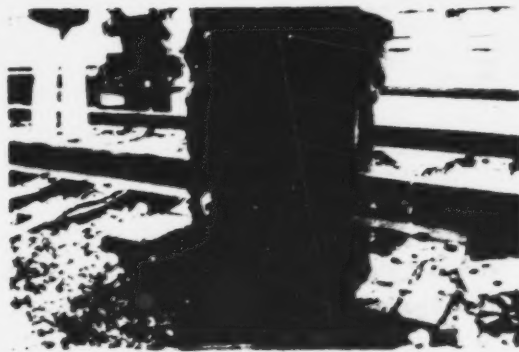


Plate 7.12 Damage from tamper tine penetration of geotextile Terrafix 400NR along with abrasion damage below tie area, presumably caused from agitation of ballast particles observed during October 1981 visit

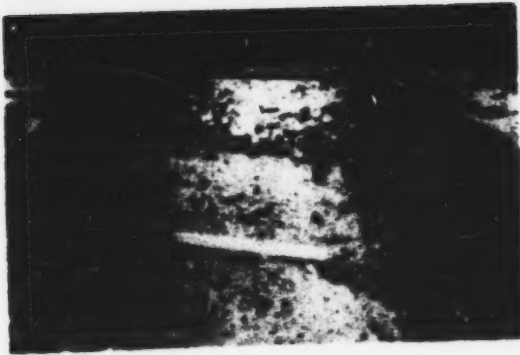


Plate 7.13 Tamper tine penetration holes created on surface of dirty ballast left in place from undercutting as observed during October 1981 visit



Plate 7.14 Shoulder drainage conditions, looking eastward along eastbound track ditch with station building in upper right corner

CHAPTER 8

INSTALLATION PROCEDURE

8.1 INTRODUCTION

Clearly evident from the observations made during the geotextile inspections was the importance of formulating a procedure for installing geotextiles during any track rehabilitation program. The most important factor to be considered when planning track rehabilitation, whether geotextiles are used or not, is the use of good drainage techniques. Geotextiles, for use as part of the solution to track problems, require careful installation if they are to function effectively.

8.2 LOCATION OF GEOTEXTILES

Most of the installations of geotextiles investigated or reported as installed in Canada have been at grade-crossings such as shown in Plate 8.1. Other common installations have been at switches, diamonds and the like. The odd lengthy installation occurred over flood plains and marshy areas with high water tables where ground water lowering was beyond the control of the railway installing the geotextile. They have been installed in areas of very poor soil conditions and drainage where the ballast has become fouled by the subballast or by the soft subgrade, or in poor drainage areas where the local drainage has been towards the tracks instead of away from them. The fact that one type of geotextile appears dominant in one region but varies from region to region suggests that rehabilitation with geotextiles has occurred without sufficient knowledge of specific site conditions. These localized applications are the target of this discussion.

8.3 SHOULDER REMOVAL FOR DRAINAGE

When fouled ballast has been removed from a track structure, it, along with the ballast shoulders, should be either ploughed to a level below the freshly prepared track surface or removed from the site altogether to permit good lateral drainage to the shoulder drainage. Dirty ballast can retard lateral drainage to the side ditches or French drains if care is not taken to adequately shape the spoil pile at the

shoulder, particularly when the spoil has been discharged as shown in Plate 8.2. Another undesirable feature shown in Plate 8.2 is the backfilling of the gopher trench with dirty ballast on the pretext of cost savings on ballast replacement. Unless water can drain away from the track area, it will pond within the track structure, softening the trackbed and facilitating its return to the original fouled condition. Lateral drainage can be quickened by preparing the undercut surface with a slight fall towards the draining edge. If the undercutting process includes trenching at the shoulder, it is advisable to slope the prepared surface to this trench. The trench should be backfilled with clean aggregate to aid side drainage and not with the fouled spoil that had been previously removed from the trackbed, as witnessed in Plate 8.2. The depth of the trench is recommended as a minimum of 150 mm (6 in.) below the prepared surface to allow for quick drainage away from the track ties. Again, the fouled ballast should be deposited below the prepared trench or removed completely for better side drainage.

The track gopher can be useful in flat regions where shallow grades have created additional drainage problems. The trench helps drain the surface water on the track away from the roadbed. If the subgrade is sandy or silty, the trench should be lined with a low-EOS geotextile to maintain a reasonable filter between the open-graded ballast and the fines. The moisture from the track will then flow towards the lower elevation of the trench and may be channelled beyond the immediate area of the track structure.

8.4 INSTALLATION BELOW LOCAL GROUND LEVEL

In locations where the geotextile will be installed below the local ground elevation, steps should be taken to guard against the inflow of water from the ground surface above the geotextile. A number of installations have shown that the ballast above the geotextile and the geotextile itself may be fouled with fines from beyond the shoulder area due to water draining into the structure, and fouling the ballast from above. Either a French drain should be installed along the edge of the track or the geotextile turned up at the sides to filter the inflow of water from above the prepared surface. The prevention of such water inflow into the track-bearing area is an added reason for establishing a trench along the side of the track during the under-

cutting process. In flat-land areas it may be necessary to construct soakaway pits away from the track structure to allow drainage of the water from the French drains.

Consideration should be given to reducing excessively-wide shoulders above the geotextile level in areas of poor drainage. The shorter drainage path will help drain the excess moisture from the track bed. In areas where reducing the shoulder widths is impractical, such as at grade-crossings, alternate methods of drainage such as French drains are recommended

8.5 INSTALLATION AT GRADE CROSSINGS

Grade-crossings foul because of a lack of adequate drainage in the central region of the crossing as revealed in Plate 8.3, by removal of the crossing planking. High-impact loads develop at the crossing upon entering and leaving the rigid track structure. The loads continue to overstress the track well beyond the grade crossing due to a harmonic motion established by the rolling stock. The higher stress placed on the subgrade will quite often generate localized pumping. For this reason, it is important to achieve a dry, stable subgrade at the crossing and similar conditions roughly 30 meters (100 ft) either side of it.

Drainage at a grade-crossing is generally parallel to the rails until the road pavement and shoulders have been cleared. The flow should then be turned perpendicular to the track to discharge into the ditch, as shown in Plate 8.4. Perforated drain pipes may also be wrapped in a geotextile and, either way, will assist the flow of water from within the crossing to the ditches beyond the crossing. The pipe should be laid directly on the geotextile in the trench prepared by the bucket wheel on the track gopher. The ends of the perforated drain pipes and the crossing geotextile should then be laid with sufficient fall towards the side ditches as shown in Figure 8.1. Whether perforated pipes are used or not in the crossing, it is advisable to remove the shoulders at the corners of the crossing and turn down the geotextile so that it facilitates drainage under gravity toward the side ditches, as seen in Plate 8.5. The shoulders could then be replaced with clean ballast above the established drainage paths. If no effort is made to provide drainage from the coarse new ballast, through the shoulder

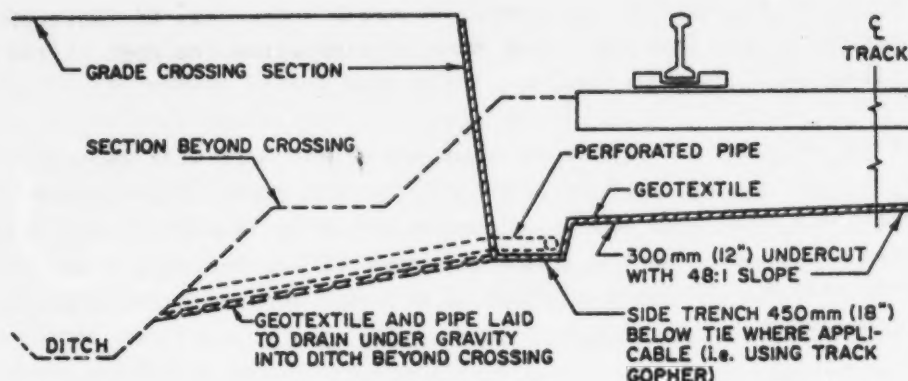


Figure 8.1 Illustration of geotextile installation at grade-crossing

material, and to the side ditches, then the water will remain in the crossing and be absorbed by the subgrade. The bathtub effect illustrated in Plate 8.6 ultimately results. This will trap water above the bearing area, resulting in softening of the subgrade soil and increased probability of track distress. Where the geotextiles are used to line the walls of the excavated crossing to prevent lateral migration of particles from beneath the road surface, they should be turned down as noted above and in Figure 8.1 to ensure lateral drainage of the crossing.

Similar inadequate drainage of the roadbed can be caused by not flattening or removing fouled shoulder ballast during an undercutting operation, as shown in Plate 8.7. This results in the water being trapped as though it were in a canal and can only escape by seepage into the roadbed bearing area.

8.6 METHODS OF INSTALLING GEOTEXTILES

Geotextiles may be installed as part of the undercutting process as seen in Plate 8.8, or by machines especially designed for the purpose as seen in Plates 8.9 and 8.10, or manually by rolling the geotextile out underneath the track by hand as seen in Plate 8.11. Once in place, it must be covered with 200 mm (8 in.) or more of ballast prior to first tamping. Otherwise the tamper tines, which penetrate about 75 mm (3 in.) below the ties and cause excessive movement of ballast to about 150 mm (6 in.) below the ties, will cause the vibrating ballast to

abrade holes in the geotextile similar to that seen in Plate 8.12. Methods which have been used to ensure reasonable ballast depths prior to first tamping include:

- . placement of short lengths of old ties between the geotextile and the tie base as seen in Plates 8.13 and 8.14
- . supporting the track with jacks under the rails as seen in Plate 8.15
- . using cotton sand bags of about 200 mm (8 in.) diameter when filled with clean ballast.

The first two methods require removal of the temporary track support which is labour-intensive. The third method is the simplest. The cotton bags, with time, rot and should not cause a future problem to track maintenance, such as clogging undercutter screens at some future upgrading of the track.

If the geotextile is of sufficient quality to withstand the harsh track environment and has been correctly installed, ballast fouling occurs either by ballast degradation or through the ballast surface from foreign sources. Clearly, good-quality ballast aggregate is a desirable asset for a geotextile installation, even if only applied over the short lengths of track where the geotextile is installed.

8.7 DEPTH OF INSTALLATION

In order to allow for future undercutting of a track and also to reduce the abrasive forces on a geotextile, it is highly beneficial to the longevity of the geotextile that it be placed as deep as possible. On the other hand, track undercutting costs increase rapidly with depth. As a compromise, a 300 mm (12 in.) depth below the ties appears to be reasonable and acceptable based on observed installation and damage depths. This depth would be deep enough to allow future shallow undercutting without having the geotextile cut into small pieces. These small pieces of geotextile can become caught in the undercutter's screens, turning the geotextile into a detriment rather than asset.

Any cost-benefit of a geotextile installation will need a site-specific analysis; however, where they are used to protect the ballast below switches and diamonds some general statements are possible. Switches, diamonds and like track structures cost today (1982) in the order of \$25,000 to \$100,000 each, depending on size, and any underlying geotextile would cover 25 to 100 m² (250 to 1000 ft²). Even if a geotextile as expensive as \$10 a square metre (\$1/ft²) were to be selected, it should only add about one per cent to the cost of the installation. In poorly-drained terrain, such a percentage cost is likely to be negligible compared to the savings from reduced maintenance and added life of the specialized track structure. Geotextiles, properly selected and installed, are therefore likely to provide substantial benefits at minimal cost.

It is worth recording that on every site where the writers extracted a geotextile, the track foremen responsible for the territory stated, without exception, that they had observed less tie maintenance in track having underlying geotextiles as opposed to track without geotextiles. While a cost cannot be assigned to such statements, it is clear that in the poorly-drained terrain of this study, the reduced tie maintenance was sufficiently significant to be observed by the day-to-day maintenance personnel.

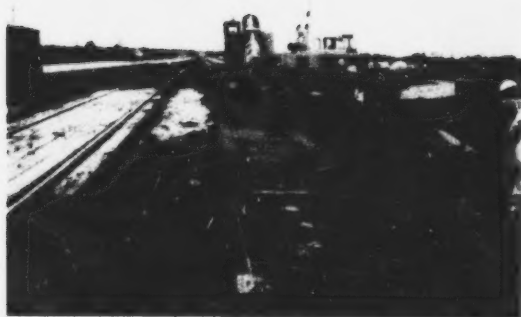


Plate 8.1 Typical grade crossing installation inspected with excavation width close to tie width



Plate 8.2 Discharging undercut dirty ballast on track shoulder helps foul shoulder ballast. Both should be levelled to trench undercut elevation to facilitate drainage from track bed



Plate 8.3 Typical fouled grade crossing with inadequate drainage at centreline of crossing highway

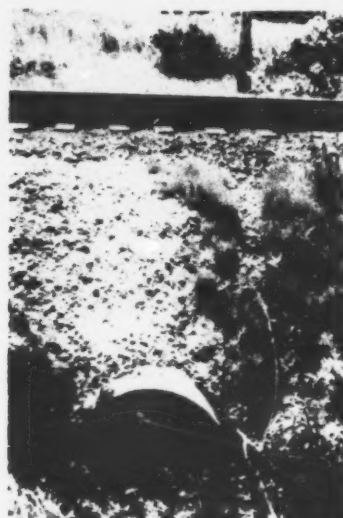


Plate 8.4

Small perforated pipe used to maintain long-term drainability of track and grade crossing through track shoulders



Plate 8.5 Geotextile turned downward at end of grade crossing to allow gravitational drainage of track bed through track shoulders and/or laterally along geotextile

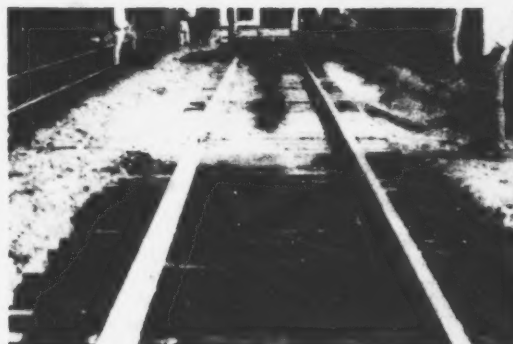


Plate 8.6 Bath tub effect produced by not removing track shoulders during grade crossing upgrading



Plate 8.7 Canal effect created by under-cutting operation where shoulder ballast is not removed



Plate 8.8 Geotextile roll attached to under-cutter



WORKING ALONG WITH THE TRAC GO-4

Plate 8.9 Laying equipment for use with heavyweight geotextiles



INSTALLS 1/2 MILE OF FABRIC WITHOUT CHANGING ROLLS

Plate 8.10 Rear view of heavyweight geotextile laying equipment



Plate 8.11
Geotextile
roll being
manually laid



Plate 8.12 Ballast - aggregate - worn holes through 700 g/m^2 (20 oz/yd^2) geotextile made by tamper agitation of ballast



Plate 8.13 Track being supported by old ties while ballast train deposits new aggregate

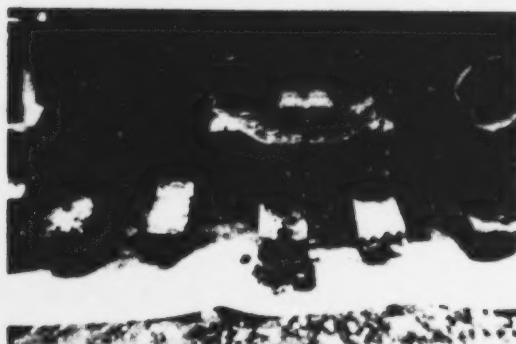


Plate 8.14 Ballast train on track being supported above geotextile by short lengths of old ties



Plate 8.15 Rail jack used to support track during ballasting



CHAPTER 9

SUMMARY AND CONCLUSIONS

9.1 SUMMARY

The railways have shown a recent interest in the use of geotextiles as a solution to some of their consistently more severe track maintenance problems. A higher level of stress, brought about by increased wheel loads, has accelerated the deterioration of many existing track structures. The mounting costs associated with short-duration, repetitive maintenance to diamonds, switches, and grade-crossings have prompted a reassessment of traditional maintenance procedures.

The proven success of geotextiles has been in the three main areas of application: erosion control, subsurface drainage, and soil reinforcement. Manufacturers have provided a wide assortment of geotextiles to cope with the diverse needs of the design engineer. Most of these products performed well in the track structure over a short period of time, but to achieve long-term stability in the harsh track environment, the choice of the geotextile to be used must become more selective.

Long-term stability is achieved by instituting a proper drainage system in and around the track structure. A geotextile should not be used in place of good drainage techniques. Effort should be given to establishing or improving the existing surface drainage. If properly installed, the geotextile will provide good lateral drainage for the excess moisture found in the roadbed, and subsequently improve the stability of the subgrade soil.

Detailed field investigations were conducted at a number of track locations where a geotextile had been installed. Specific site observations and laboratory analyses of selected soil and geotextile samples were used to assess the in-track performance of the installation. Particular interest was given to the installation procedure because of its effect on the geotextile's in-service life.

The following conclusions were made from the field investigation program:

- (1) Geotextiles have primarily been installed in areas of poorly draining, flat and marshy terrain. Most of these sites were unable to achieve proper drainage because of the locally or seasonally high water table.
- (2) Geotextile drainage was non-existent at sites where the side drainage was unreachable or non-existent. Buried drain pipes and French drains should be considered essential in such areas as grade-crossings, diamonds and switches located in poorly drained terrain to help transport the excess moisture away from the immediate track structure.
- (3) In areas where side drainage was available, the geotextile had a significant influence on the maintenance of dry ballast above the geotextile/soil interface.
- (4) Needle-punched, non-woven geotextiles provided better lateral drainage than either woven or the heat-(spun-)bonded, non-woven geotextiles.
- (5) The more open geotextiles were susceptible to clogging, especially in areas of actively pumping track. EOS and lateral permeability tests were formulated to assess the degree of clogging. The particles that became trapped within the fiber structure helped abrade the geotextile internally as well as reduce its permeability. The heavier, well-needle-punched geotextiles supported EOS values of less than 38 microns (No. 400 sieve size) and appeared to resist clogging better than the more-open, lighter, needle-punched or heat-(spun-)bonded geotextiles.
- (6) Thin geotextiles such as the monofilament woven and heat-bonded, non-woven products proved unsuccessful in the track environment. Their lesser abilities to conduct water in the plane of the geotextile created additional stability and drainage problems in the track structure.

- (7) In areas where poor-quality ballast was used above the geotextile, the filtering capability of the geotextiles tended to be reduced by aggregate degradation.
- (8) In all cases, geotextiles have maintained, over a short period of time, a certain amount of particle separation between existing dirty ballast and new ballast. Their performance can be measured to a large degree by comparing the particle distribution above and below the geotextiles. On a long-term basis, geotextiles, if not correctly selected and installed, can intensify track instability.
- (9) In track rehabilitation applications, tensile strength is of secondary importance to impact and abrasion strength. The geotextile will have sufficient tensile strength if it can meet the requirements for abrasion and impact resistance.
- (10) Needle-punched, non-woven geotextiles with a high density of needling have superior resistance to abrasion and impact than either needle-punched geotextiles with a low density of needling or heat-bonded geotextiles. Needle-punched, non-woven geotextiles showed improved resistance after being dipped in a synthetic resin and forced-air-dried. The resin coating secured the fibre interlock and protected the fibres from particle abrasion.
- (11) Abrasive damage to geotextiles was observed to be greatly reduced at excavation depths below the ties of 250 mm (10 in.) or greater. Considering the fact that settlement from ballast degradation and compaction will occur, a reasonable installation buried depth for the geotextile below the base of the tie would be 300 mm (12 in.).
- (12) Some environmental damage, although slight and possibly unimportant, was evident for the non-polyester polymers. Until further evidence has been obtained, only polyester should be used for track rehabilitation geotextiles.
- (13) In view of the damage observed even to 500 g/m² (14 oz/yd²) geotextiles doubled in thickness, albeit at less than 300 mm (12 in.) below the ties, it is evident that a minimum weight for a track rehabilitation of well-needle-punched geo-

textile made from polyester should be 700 g/m² (20 oz/yd²) if resin-dipped and forced-air-dried, and placed at least 300 mm (12 in.) below the ties of continuous-welded rail track. This weight would increase to 1000 g/m² (29 oz/yd²) below discontinuities (i.e. rail joints, switches, diamonds). These weights need to be doubled where the geotextile is non-resin-dipped and also increased if the installation depth is decreased. Under no circumstance is it desirable to tamp track with less than 200 mm (8 in.) of ballast between the geotextile and the base of the tie.

- (14) Guidelines for a specification based on the laboratory testing would specify the following:
- (a) weight: as per conclusion (13)
 - (b) resin binder: between 5 to 15 per cent by weight
 - (c) polymer: polyester
 - (d) EOS: less than 38 mm (No. 400)
 - (e) manufacturing process: needle-punched, resin-dipped and forced-air-dried
 - (f) abrasion resistance: less than 50 per cent loss in modulus after 1000 cycles of H-18 stone, 1000 g using Tabor Abrasor and Queen's Tensile Tester
 - (g) impact resistance: no major damage after 10 drops with steel plate base.

CHAPTER 10

SUGGESTIONS FOR FURTHER STUDY

From the results of this investigation, the following recommendations are made for further study:

- (1) The basis of this report was established on information gathered from a select number of geotextile installations. These sites provided enough facts to establish that some problems associated with track maintenance can be improved by proper installation methods of competent geotextiles. Tests should be set up using geotextiles consistent with the weights recommended in this report -- that is, using super-heavyweight geotextiles compared with those generally available on the open market.
- (2) The track support structure at many of the visited locations no longer resembled a standard track design of ballast, subballast and subgrade. Typically, the subballast layer was mixed with the softer subgrade soil below and had been removed in part, with the replacement of the fouled ballast above. With time, the entire subballast layer would cease to exist. A soil profile taken in stable track near to the problem area would serve as a useful comparison to the changed soil conditions in the unstable track section.
- (3) Heavier geotextiles and composite geotextiles should be considered for use in any planned new testing program, in view of the fact that the existing products are still not performing sufficiently well. Developments towards a composite geotextile should be explored. The multi-layered product should include highly-abrasive-resistant outer layers and a porous internal layer to conduct the water flow. An example as a possible first trial is shown in Figure 10.1.
- (4) Test sections or selected installations should be constructed and monitored for the purpose of assessing the performances of a number of geotextile types in a controlled environment. Any test results should be used to statistically relate

the field performance of each geotextile with the laboratory assessment. Particular attention should be paid to any variation in drainage between differing installations.

FUTURE MULTI-LAYER GEOTEXTILES

<u>300 g/m² (min)</u>	}	LOW EOS - 3 DENIER -
		RESIN DIPPED - NEEDLE PUNCHED
<u>500 g/m² (min)</u>	}	HIGH EOS - LARGE DENIER -
		RESIN DIPPED - NEEDLE PUNCHED
<u> </u>	}	AS UPPER LAYER
<u> </u>		

Figure 10.1 Multi-layer geotextile, needle-punched together into single unit

REFERENCES

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APPENDIX A

DEVELOPED LABORATORY TESTS FOR GEOTEXTILES

- A.1 Geotextile Equivalent Opening Size (EOS) Test
- A.2 Geotextile Ballast Impact Test
- A.3 Lateral Permeability of Geotextiles
- A.4 Geotextile Tensile Rupture Test
- A.5 Geotextile Aggregate Abrasion Test
- A.6 Capillary Test for Geotextiles

A.1 GEOTEXTILE EQUIVALENT OPENING SIZE (EOS) TEST

SCOPE

This method determines the 'Equivalent Opening Size' (EOS) of a geotextile in terms of U.S. standard sieve sizes or physical sieve opening size.

DEFINITION

The Equivalent Opening Size (EOS) is defined as either the number of the U.S. standard sieve having mesh openings closest in size to the geotextile openings or the millimetre physical opening size of the same sieve.

APPARATUS

The apparatus shall consist of the following:

- a suitable clamp for firmly holding a 210 mm diameter piece of geotextile; such a clamp is illustrated in Figure A.1.1
- a range of rounded sand¹ as appropriate for the fabric under test
- a nest of U.S. standard sieves for sorting the sand to size
- a table to support the fabric during installation (190 mm diameter, 30 mm high, for the geotextile clamp shown in Figure A.1.1)
- a wire brush suitable for cleaning the sieves
- some 6 mm diameter ball bearings
- a 'RO-TAP' sieve shaker.

¹ Glass beads may also be used but are not recommended in humid climates because 'static electricity' often affects the passage of the beads through the geotextile.

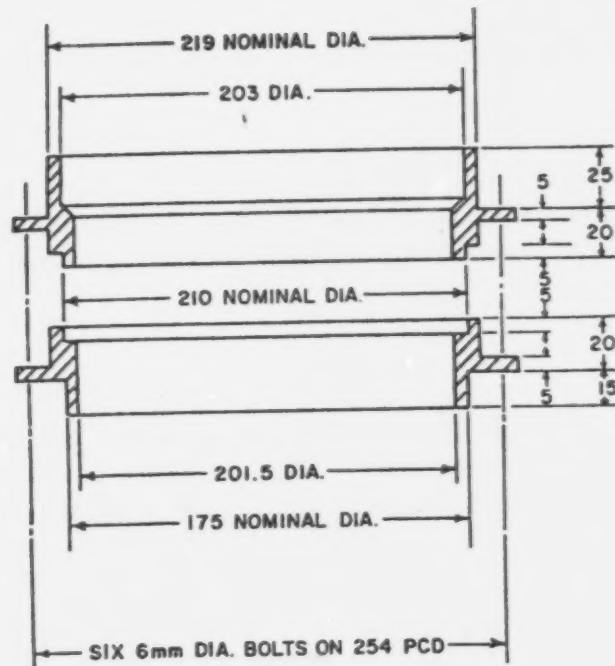


Figure A.1.1 Fabric clamp for EOS test (dimensions in mm)

PREPARATION OF SAND

The sand shall be sieved to obtain at least 50 grams of each fraction for use in the EOS test. In order to ensure a good separation of sand sizes during sieving, the sand should be oven-dried prior to use and about five 6 mm diameter ball bearings placed on each sieve. The ball bearings vibrate the sieve mesh and minimize the retention of under-sized sand particles, a major problem for good repeatability since the graded fraction must be uniform to ensure repeatability of the EOS test.

Dependent on the sand sizes required for the geotextile to be tested, the sieves listed in Table A.1 shall be used.

TABLE A.1
SIEVE SIZES

Designated	EOS Passing		Retained On	
	Sieve No.	Micron Size	Sieve No.	Micron Size
20	18	1000	20	840
30	25	710	30	590
40	35	500	40	420
50	45	350	50	297
70	60	250	70	210
100	80	177	100	149
140	120	125	140	105
200	170	88	200	74
270	230	62	270	53
400	325	45	400	38

PROCEDURE

The tests shall be repeated on five unaged and undamaged samples of geotextile. Both the geotextile and sand to be used for testing shall be in an oven-dry state and cooled in a desiccator prior to immediate use.

- (a) Cut the geotextile to size and oven dry at a temperature of 105°C or at a temperature insufficient to damage or shrink the geotextile. Prior to testing, but after drying and cooling, the geotextile should be weighed.
- (b) Place a piece of oven-dry geotextile in the clamping device such that the sand cannot by-pass the geotextile when placed in the device. Mark or note the test side of the geotextile.
- (c) Place an empty sieve pan below the clamped geotextile and no more than one sieve above the clamping device.

- (d) Place one of the oven-dry sand fractions on the geotextile and attach a lid to the assembled sieves. The test should be started with a sand fraction at least 95 per cent by weight of which passes through the geotextile, and then repeated with the next largest fraction. Where the geotextile has a physical opening size which is small (large sieve equivalent), the test should be started with a No. 200 sieve size sand and then decreased or increased as appropriate.
- (e) The assembly shall then be agitated on a sieve shaker for at least twenty minutes with the clamped geotextile near the top of the shaking device.
- (f) Weigh the material both passing and retained on the geotextile.
- (g) Remove, as best possible without damaging the geotextile, any material trapped such that the test specimen returns to its initial weight. If necessary, compressed air or an ultrasonic cleaner may be used. If moisture reaches the geotextile, it should be oven dried between sievings.
- (h) Repeat the above procedures using, progressively, the next coarsest sand fraction until more than ninety-five per cent by weight of the appropriate fraction size is retained on the geotextile, always using the same test side. Because of possible breakage during sieving, the sand should be resieved after use to ensure that the material passing through the geotextile is of the correct size.
- (i) Repeat the above procedures using the reverse side of the geotextile test specimens.

REPORT

Report the per cent by weight of sand retained, trapped in and passing of each nominal sand size used for each side of each of the five geotextiles tested. The smaller the spread between the per cent retained and the per cent passing gives an indication of the uniformity of opening size through the thickness of the geotextile. Also report the

five values for each test side of 'per cent passing' U.S. standard sieve number for which the smallest sand size (i.e. largest sieve number) was five per cent or less passing the geotextile. The Equivalent Opening Size (EOS) is taken as the smallest of the five sieve numbers (i.e. largest opening size unable to pass five per cent of the sand through the geotextile).

An alternative definition of the Equivalent Opening Size may be taken as the largest opening size sieve number (i.e. smallest physical size) unable to pass or trap 95 per cent of the sand by the geotextile (i.e. 95 per cent or more retained). This alternative regards the trapped sand as passing sand and should be referred to as 'EOS based on percentage both trapped and passing'. The major problem with this 'trapped and passing' definition is that when recovering the retained sand, the more the clamping device is tapped the more trapped sand appears as retained sand.

Any difference in the two sides of the geotextile should be noted.

QUEEN'S UNIVERSITY
KINGSTON, ONTARIO
GEOTECHNICAL TESTING LABORATORY - ELLIS HALL
ENGINEERING FABRIC TESTS

Sample Marked:

Date Received:

Date Tested:

Tests Performed:

Equivalent Opening Size:

Sieve No.	Weight Passing	%	Weight Retained	%	% Trapped

Sieve No.	Weight Passing	%	Weight Retained	%	% Trapped

Sieve No.	Weight Passing	%	Weight Retained	%	% Trapped

Sieve No.	Weight Passing	%	Weight Retained	%	% Trapped

Tested For
Tested By
File No.

Approved
.....
Professor of Civil Engineering

Figure A.1.2 Sample report form

A.2 GEOTEXTILE BALLAST IMPACT TEST

SCOPE

This method of testing provides a means of assessing the damage caused by ballast placement from ballast cars on a geotextile used for track support soil separation.

APPARATUS

The apparatus is illustrated in Figure A.2 and consists of:

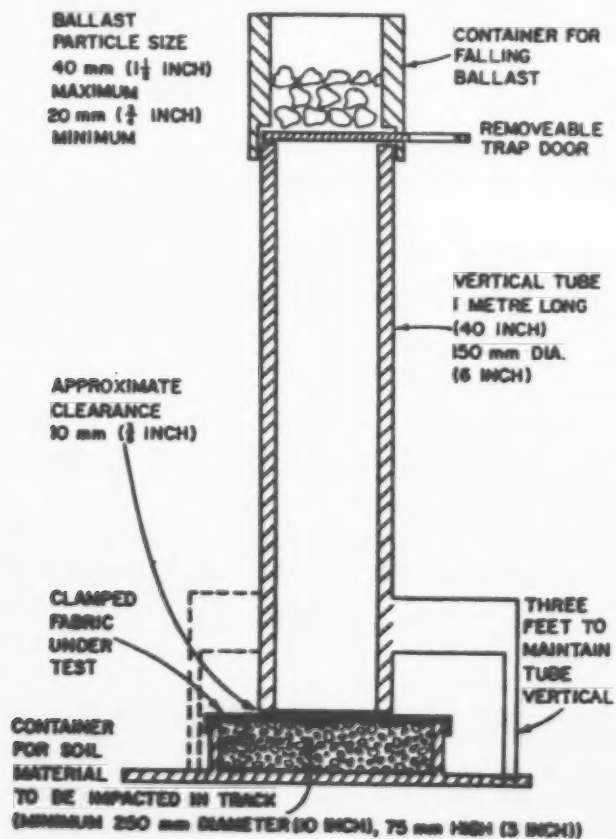


Figure A.2 Apparatus for ballast impact test

- (a) a box or cylinder to contain soil similar to that in track upon which a geotextile is to be laid. The container shall have inside dimensions not less than 250 mm diameter by 75 mm high. A square container may be used.
- (b) a vertical tube not less than 1 meter long, with a nominal diameter of 150 mm. The use of schedule 40 six inch pipe is suggested.
- (c) a removable trap door covering the upper end of the 150 mm diameter vertical tube.
- (d) a container for ballast specimens of equal diameter to the vertical tube. Lugs attached to this container shall allow alignment of its inside diameter with the inside diameter of the vertical tube.

PROCEDURE

The procedure consists of the following:

- (a) Place, by compaction if necessary, and then smooth the surface of the soil (similar to that in track upon which the geotextile is to be laid) in the lower container shown in Figure 2.A. The soil should be placed at a similar density to that expected in the field. Where an excessively-severe test is required, a metal disc should be placed in the lower container so as to fill the container.
- (b) Lay the geotextile to totally cover the soil surface. Clamp the geotextile in such a manner that no wrinkles exist on the surface of the geotextile covering the soil (or metal disc). Mark or note the test side of the geotextile.
- (c) Place the 150 mm diameter tube vertically over the centre of the geotextile/underlining soil container such that the tube is not touching the geotextile and the clearance does not exceed 15 mm. The vertical tube should be fixed in such a manner that it may be removed and replaced in the same location over the centre of the geotextile.

- (d) Place the trap door and ballast container at the top of the vertical tube as shown in Figure A.2.
- (e) Place not less than 5 kg of ballast whose particle size passes the 40 mm sieve and is retained on the 20 mm sieve in the upper ballast container.
- (f) Remove the trap door rapidly without disturbing the vertical tube so that the ballast falls freely to impact the geotextile.
- (g) Carefully remove the vertical tube and collect the fallen ballast for reuse.
- (h) Repeat procedures (c) to (g) four additional times, for a total of five ballast impacts.
- (i) Measure the Equivalent Opening Size of the tested impacted geotextile.
- (j) Measure the Equivalent Opening Size of the same geotextile untested, as supplied from the manufacturer.
- (k) Repeat the test on the reverse side of the geotextile using an untested specimen of the same geotextile.

REPORT

Report the Equivalent Opening Size of the untested geotextile as supplied from the manufacturer and the Equivalent Opening Size of each side of tested impacted geotextile. Report the type of ballast material used and container soil material used, along with the latter's density and moisture content in relation to standard proctor density and moisture content.

Report also any visual damage to the geotextile observable under a five-times magnification lens.

Any difference in the performance of the two sides of the geotextile should be noted.

A.3 LATERAL PERMEABILITY OF GEOTEXTILES

SCOPE

This test is intended to determine what is defined by some as the coefficient of permeability and by others as the hydraulic conductivity of a non-woven geotextile due to water flowing in the plane of the geotextile. The test allows for a variable stress normal to the plane of the geotextile. The determination is by use of a falling head or fixed head procedure with water flowing radially in the plane of the non-woven geotextile. The test is not suitable for testing woven geotextiles.

APPARATUS

The apparatus shall consist of the following:

- (a) permeability mold as shown in Figure A.3, consisting of a metal mold and piston
- (b) transparent standpipe. A standpipe shall be connected to the central inlet of the permeability mold. Standpipes of various diameters shall be available so that during the test the rate of fall of the water level shall not exceed 10 mm per second.
- (c) thickness control device. A means of attaching a dial gauge to the piston shall be provided so that the thickness of the geotextile between the plunger and the permeameter is known at all times.
- (d) a dial gauge
- (e) water supply apparatus at room or measured temperature shall be fitted through a stopcock to the standpipe and shall be at the same temperature as the permeameter and geotextile
- (f) miscellaneous apparatus, including a scale and a stop watch.

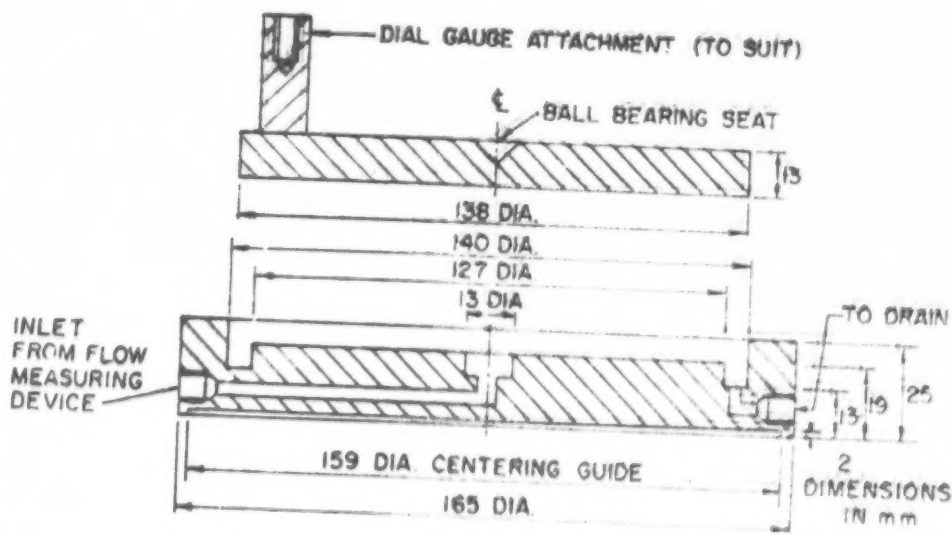


Figure A.3 Permeability mold for lateral permeability test

PREPARATION OF SPECIMEN

After carefully cleaning both faces of the apparatus, place the plunger in position and set the dial gauge to a zero thickness reading. A circular disc of geotextile of similar diameter to the plunger shall then be cut and placed in the permeameter. For thick geotextiles, or where found to affect the test results, a small hole should be made in the centre of the geotextile disc of approximately but not more than 13 mm diameter.

PROCEDURE

The procedure for testing the lateral permeability or hydraulic conductivity of a geotextile is as follows:

- (a) Place the desired constant test load on the plunger. Allow ten minutes for the geotextile to compress.
- (b) The test specimen should be saturated from the water supply which has been allowed to stabilize to the same temperature as the permeameter and geotextile.

- (c) The head of water in the standpipe may be obtained by opening the stopcock on the water supply apparatus and slowly forcing water from the water supply up the standpipe.
- (d) Once the head has been raised in the standpipe, the stopcock should be closed and the time recorded for the water to drop in the standpipe by flowing laterally and radially through the geotextile. Several readings should be taken. Thickness dial gauge readings should also be recorded and may be found to vary by a small amount during the test.
- (e) Double the plunger load and repeat the test. Obtain values for at least four different loads each time, doubling the existing plunger load.
- (f) When the desired maximum load has been reached, halve the existing load and repeat the test. Continue halving the load until the starting load has been reached, performing a test at each load increment.

CALCULATIONS

Assuming that the water flow through the geotextile is laminar, the coefficient of permeability of hydraulic conductivity (depending on definition) in units of length per unit time may be calculated from the head drop readings as follows:

$$k = \frac{A_s \log H_1/H_2}{2 \pi z \cdot (t_2 - t_1) \log (R_2/R_1)}$$

where: A_s = the cross-sectional area of the standpipe
 H_1 = the standpipe head at time t_1
 H_2 = the standpipe head at time t_2
 z = the thickness of the fabric
 R_1 = the inner radius of the permeameter
 R_2 = the outer radius of the permeameter

To facilitate the calculations and to check the accuracy of the test, the falling head readings should be plotted on semi-log graph paper as logarithm of hydraulic head against time on a natural scale. If the water flow is laminar, then a straight-line result should be obtained whose slope gives the value of $(\log H_1/H_2)/(t_2-t_1)$. Some curvature may result if the geotextile thickness does not remain constant during the test or, in permeable geotextiles, a phreatic surface develops. The latter, if it occurs, would develop at low heads, causing a flattening of the slope of the plots.

REPORT

Report the permeability (conductivity) and thickness of the geotextile for each load for which the test was performed.

A.4 GEOTEXTILE TENSILE RUPTURE TEST

SCOPE

This method of testing provides a means for assessing the ability of a test specimen of geotextile to resist rupture during deformation caused by the application of a uniform load. Both the deformation and rupture characteristics of the geotextile to the application of the loading may be obtained.

APPARATUS

The apparatus is illustrated in Figure A.4 and consists of:

- (a) a 152 mm circular or square, 13 mm thick aluminum upper plate with a 102 mm diameter circular opening. Two shallow, narrow, circular grooves are milled into the underside of this plate adjacent to the opening. Six or more equally-spaced 6 mm diameter holes are drilled around the circumference of the opening on a 140 mm pitch diameter.
- (b) a thin rubber membrane of about 135 mm diameter is required for each test
- (c) a 152 mm circular or square, 25 mm thick, lower plate with a 114 mm diameter, 6 mm high raised area. The area of contact between the upper plate and raised circular section of the lower plate includes the milled grooves. Air under pressure is supplied through a 3 mm diameter hole drilled horizontally to the centre of the plate and then vertically through the raised section. Matching 6 mm diameter holes are bored to accept the bolts to clamp the plates together.
- (d) a 15 mm x 19 mm x 152 mm aluminum bar, supported by 6 mm diameter steel rods at a suitable height above the plates. This bar carries a 50 mm travel dial gauge.

- (e) six 6 mm diameter high-strength steel bolts and wing nuts to clamp the plates together
- (f) a 50 mm travel dial gauge with 10 mm long plastic tip. The tip should be flexible enough to bend under rapid loading.
- (g) a 116 mm internal diameter, 132 mm outside diameter metal washer 6 mm high with 2 shallow grooves on the upper face.
- (h) a compressed air supply with suitable pressure-regulating valve of sufficient capacity to rupture the geotextiles requiring test evaluation.

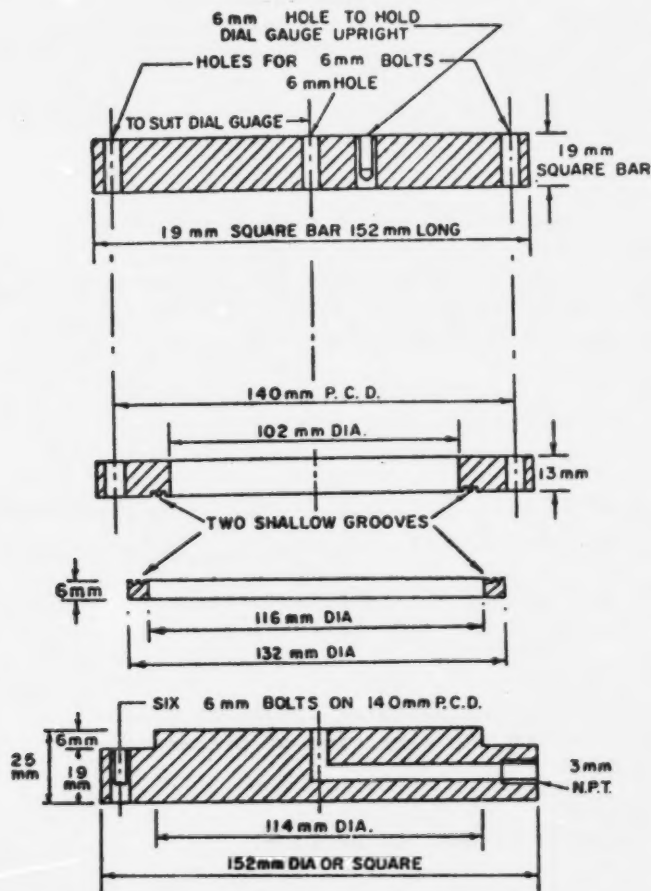


Figure A.4 Apparatus for tensile rupture test

PROCEDURE

The procedure for static testing to failure consists of the following:

- (a) Place a thin 135 mm rubber membrane between the upper and lower plates.
- (b) Place the metallic grooved washer on the rubber membrane so that the upward facing grooves will help to prevent the geotextile from slipping.
- (c) Place a 135 mm diameter sample of the material to be tested on the rubber membrane and metal washer and then the upper plate and clamp tight so the material will not slip under load. Mark or note the upper or lower face of the geotextile under test.
- (d) Adjust the dial gauge to zero with the probe just touching the upper surface of the geotextile sample.
- (e) Allow air under pressure to incrementally enter the apparatus. Incremental steps should be selected to suit the strength of the geotextile but should not be greater than 25 kPa up to 100 kPa or 50 kPa above 100 kPa.
- (f) Record the applied pressure and the central deflection after an application time of at least 60 seconds.
- (g) Continue the test to rupture or to a predetermined maximum pressure.
- (h) Repeat the test on at least five untested specimens using the same geotextile upper surface.
- (i) Repeat the test on untested specimens of the geotextile with the direction of placement reversed.

This apparatus may also be used to perform:

- . steady creep tests, with stepped increments on a fixed schedule
- . repetitive load tests, with the pressure cycling between two preset limits.

Where appropriate, recording apparatus can be incorporated to time and count cycle applications.

REPORT

Report the dial gauge readings corresponding to the applied pressure and the rupture pressure of the tested specimens.

Any difference in the performance of the two sides of the geotextile should be noted.

A.5 GEOTEXTILE AGGREGATE ABRASION TEST

SCOPE

This method of testing provides a means of assessing the damage caused by aggregate (ballast or subballast) on a geotextile used as a separation layer in track support.

APPARATUS

The apparatus is illustrated in Figure A.5 and consists of:

- (a) a 250 mm diameter cylinder, 300 mm high, closed at one end. A flange may be added at the other. A schedule 40 pipe 250 mm diameter is suggested for use as the cylinder.
- (b) a rigid circular disc 99 mm diameter
- (c) one or two 20 mm foam rubber discs 250 mm diameter. The unloading spring modulus of the foam rubber measured with the 99 mm diameter disc centrally located on the rubber shall approximate 50 MN/m³. For foam rubber the value is generally quite variable with a value of half the above at zero load, and four times the above at full load (290 kN/m²).
- (d) a 6 mm thick foam rubber for lining the 250 mm diameter cylinder whose size is approximately 250 mm x 785 mm. The unloading spring modulus of the foam rubber lining measured with the 99 mm diameter disc centrally located shall approximate 100 MN/m³. Again, a tangent modulus of half the above value may be expected at zero load.
- (e) a repeated-loading footing device. An air-activated diaphragm loading piston of 77.4 cm² area allows a direct reading of air pressure equal to the contact pressure between the rigid disc and the aggregate surface. The footing should be fixed to move in the vertical direction only (no rotation).

- (f) some lightweight geotextile, typically 140 g/m²
- (g) a dial gauge with at least 25 mm travel with 2.5 mm divisions.

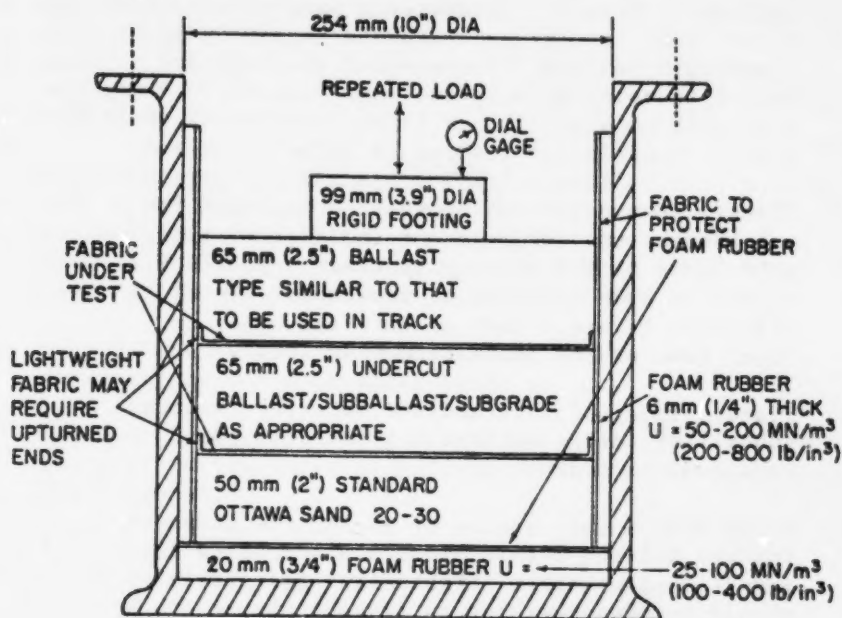


Figure A.5 Apparatus for aggregate abrasion test

PROCEDURE

The apparatus and materials to be tested should be set up as illustrated in Figure A.5. The procedure consists of the following:

- (a) Place one or two 20 mm foam rubber discs in the bottom of the cylinder, depending on the severity of test required. Two discs will allow more movement than one, resulting in greater abrasion.
- (b) Cover the foam rubber with a protective geotextile to minimize abrasion of the foam rubber.
- (c) Place the 6 mm foam rubber and its protective geotextile about the internal circumference of the cylinder. The foam rubber should be butt-

jointed, while a minimum 25 mm overlap is suggested for the protective geotextile.

- (d) While holding the rubber and geotextile lining, pour and level a 50 mm depth of sand into the cylinder. Standard Ottawa sand passing a 0.84 mm sieve (U.S. No. 20) and retained on a 0.59 mm sieve (U.S. No. 30) is suggested as an alternative to material subgrade sand from the construction site if this is not available, or if highly variable and testing is to be minimized.
- (e) Place a test sample of geotextile proposed for use between the subgrade and the adjoining aggregate layer on the sand. Lightweight geotextiles should be made oversize to prevent mixing of different layers. Mark or note the upper or lower face of the geotextile under test.
- (f) Place a layer of intermediate material (subbase, subballast, dirty ballast, or the like, as required) to a depth of 65 mm.
- (g) Cover with a test sample of geotextile proposed for use between the intermediate aggregate layer and the upper layer. Lightweight geotextiles should be made oversize to prevent mixing of different layers. Mark or note the upper or lower face of the geotextile under test.
- (h) Place a layer of the upper aggregate (base, top ballast or like material) to a depth of 65 mm.
- (i) If a vibrating table is available, the apparatus may be vibrated to cause soil densification.
- (j) Place the rigid footing centrally on the upper surface so that it may not rotate or move horizontally, but may move vertically.
- (k) Place the dial gauge in position to measure the vertical movement of the footing.
- (l) Place a small seating load on the footing of about 35 kN/m² average contact pressure and zero the dial gauge.
- (m) Repeatedly load (and fully unload) the footing to a maximum pressure of 290 kN/m². The frequency

of loading will vary with the amplitude of deformation and type of equipment used.

- (n) Dial gauge readings, loaded and unloaded, should be read at frequent intervals of not less than one logarithmic cycle of loading (i.e. 1, 10, 100, etc.). After bedding down an amplitude of about 2.5-5.0 mm may be expected for a test with one layer of 20 mm foam rubber and twice this amplitude for two.
- (o) Stop the test after the specified number of cycles and carefully dismantle the equipment. If material has worked around the geotextiles under test in sufficient quantity to affect the results, the test should be repeated.
- (p) Measure the Equivalent Opening Size of the two different geotextiles under test.
- (q) Measure the Equivalent Opening Size of the same two geotextiles untested as supplied from the manufacturer.
- (r) Repeat the test on an untested specimen of the geotextile with its direction of placement reversed.

RESULTS

Plot the dial gauge readings, loaded and unloaded, against the logarithm of the number of cycles of load.

REPORT

Report the values of Equivalent Opening Size for the tested and untested geotextiles along with the plot of deformation against logarithm of number of load cycles.

Any difference in the performance of the two sides of the geotextile should be noted.

A.6 CAPILLARITY TEST FOR GEOTEXTILES

SCOPE

This method of testing provides a means for assessing the capillary rise associated with a particular geotextile.

APPARATUS

The apparatus is illustrated in Figure A.6 and consists of:

- (a) a flat pan denoted as the reservoir source
- (b) a stand and crossbar(s) apparatus with vertical adjustment
- (c) a measuring stick positioned on the stand to mark the height of the crossbar(s)
- (d) an evaporating dish per test specimen which shall be kept below the reservoir source to maintain a syphon effect
- (e) weights for each specimen so as to maintain each geotextile in light tension throughout the test.

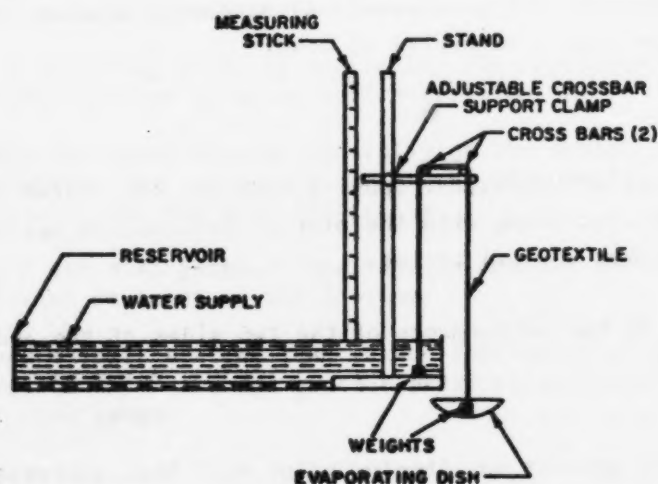


Figure A.6 Apparatus for capillarity test

PROCEDURE

The procedure consists of the following:

- (a) Prepare the geotextile sample to a standard size of 750 mm x 60 mm.
- (b) Attach a counterweight to each end of the sample.
- (c) Add water labelled with a suitable dye (such as food colouring) to an appropriate marked level in the reservoir pan.
- (d) set the crossbar(s) to the desired initial height (normally 250 mm above the water surface).
- (e) drape the dry geotextile over the crossbar(s) with one end in the reservoir pan and the other in a clean, dry evaporating dish placed below the water level of the reservoir.
- (f) lower the crossbar(s) 50 mm per day until flow is observed. This should be apparent from the residual in the evaporation dish.
- (g) record the height at which syphoning occurs. This is the height through which capillary action in the geotextile is capable of raising water.

REPORT

Report the height of rise.



APPENDIX B

PRELIMINARY SITE INVESTIGATIONS

B.1 OAKVILLE SUBDIVISION, MP 21.96,
Kerr Street, Oakville

Background Information:

type of installation: grade-crossing
fabric installed: Texel 100-M, 135 g/m² (4 oz/yd²)
date of installation: 1980
estimated tonnage: 12.4 million gross tonnes per year
(13.7 MMGT)
additional notes: subgrade material is from the Queenston
Shale Formation

Site Information:

date of visit: June 7, 1981
weather conditions: sunny and dry

A general view of the crossing taken from north of the tracks looking west is shown in Plate B.1. The topography at this site was flat, typical of the Queenston Shale Formation of this area. The track ballast was a Dolomite limestone. The tracks were pumping approximately 15 m (50 ft) on either side of the grade-crossing. This, while evident in Plate B.1 for the north track, was particularly noticeable in the north track where the ties were not only submerging into the fouled ballast but the condition of running rail was evident, as shown in Plate B.2. The track shoulders and the ditches were virtually non-existent. The water trapped between the two tracks had been draining to the shoulders through surface trenches located between the ties. Most of the water appeared to run off to the north side of the track. Vegetation, a good indicator of soil particles in the ballast, was growing both between the tracks next to the crossing and along the shoulders, indicating that during the installation of the geotextile drainage improvement along the trackbed had not been undertaken.

Insufficient drainage on the surface and within the track structure was contributing to the pumping track condition. The flat topography limits the effectiveness of deepening the ditches and the track cannot be raised without causing further problems with the street grade and overhead wires. Therefore, consideration needs to be given to improving the drainage paths below the track. Possible improvements which should be considered are the use of wrapped drainage pipe under the crossings and French drains under the shoulders and between the two tracks, discharging into soakaway pits near the property line.

B.2 OAKVILLE SUBDIVISION, MP 24.42,
Third Line, Oakville

Background Information:

type of installation:	grade-crossing
fabric installed:	Texel 100-M, 135 g/m ² (4 oz/yd ²)
date of installation:	1980
estimated tonnage:	12.4 million gross tonnes per year (13.7 MMT)
additional notes:	subgrade material is from the Queenston Shale Formation

Site Information:

date of visit:	June 7, 1981
weather conditions:	sunny and dry

A general view of the crossing looking east is shown in Plate B.3. There were four tracks at this grade-crossing, two mainline tracks and two industrial spur lines south of the main lines. The tracks were constructed on relatively flat ground. There was little change in elevation between the top of the Dolomite ballast and the ditch lines. The south track has drainage problems created by the tracks on either side. Furthermore, as may be seen in Plate B.3, weeds are growing on the sides of the track's ballast shoulders, indicating that when the track was undercut to install the geotextile no provision was made for lateral drainage of the undercut area. The ballast around the ties at the crossing was beginning to foul.

Plate B.4 shows a small trench constructed across the north track, obviously built to drain the water caught between the two mainline tracks. The mud in this trench had dried and cemented the ballast, effectively reducing the ballast's ability to absorb the impact from the wheel loads leaving the crossing.

B.3 KINGSTON SUBDIVISION, MP 218.18,
Elmwood Drive, Belleville

Background Information:

type of installation: grade crossing
fabric installed: Terrafix 300N, 500 g/m² (14.6 oz/yd²)
date of installation: 1977
estimated tonnage: 15.5 million gross tonnes per year
(17.1 MMGT)
additional notes: two tracks, in cut, subgrade soil mapped in
Sidney Group, a dark-grey clay, poor drainage

Site Information:

date of visit: June 10, 1981
weather conditions: overcast and raining

A general view of the two mainline level crossings at Elmwood Drive is shown in Plate B.5. The crossing was located at the perimeter of a cut section. The ditches are very shallow and have been overgrown with vegetation, as seen in Plate B.6. There were no apparent signs of major fouling or a geotextile in-track, although some fine particles were noticeable at the centreline surface of the track, as seen in Plate B.7, indicating poor drainage. Nevertheless, the track was performing reasonably well. The north track appears to have been upgraded recently with a resurfacing of slag ballast.

A profile of the subgrade soils was completed at the property line with the aid of a hand auger. The top of the hole was at approximately the same elevation as the top of the ties and the auger hole was about 1.37 m (4.5 ft) deep. The top 150 mm (6 in.) was a dark-brown top soil, underlain by 750 mm (2.5 ft) of brown sand. The brown sand changed to a brown-grey sandy silt at about 900 mm (3.0 ft) and then to a grey silt with some clay at the bottom of the hole. The following notes were recorded in the field:

<u>Sample Number</u>	<u>Depth (mm)</u>	<u>Soil Type</u>	<u>Laboratory Description</u>
1	300- 600	Brown Sand	silty fine sand, trace clay
2	600- 900	Brown Sand	sandy silt, some clay
3	900-1200	Brown-grey	well graded clayey silt, some sandy clay sand
4	1200-1370	Brown-grey	well graded clayey silt, some clay sand

A laboratory sieving of samples indicated the following:

<u>Sample</u>	<u>Field m/c (per cent)</u>	<u>Percentage Passing</u>			
		<u>0.2 mm</u>	<u>0.06 mm</u>	<u>0.02 mm</u>	<u>0.006 mm</u>
1	14.6	93	42	21	13
2	18.3	98	60	33	17
3	23.7	93	73	53	41
4	31.3	86	68	52	45

B.4 KINGSTON SUBDIVISION, MP 219.0,
east switch, Track No. 3, Belleville

Background Information:

type of installation:	switch
fabric installed:	Bidim C-38, 340 g/m ² (10 oz/yd ²)
date of installation:	1979
estimated tonnage:	15.5 million gross tonnes per year (17.1 MMGT)
additional notes:	subgrade soil mapped in Solmesville Group, a grey-brown clay loam, imperfect drainage

Site Information:

date of visit:	June 10, 1981
weather conditions:	overcast and raining

The east switch installation was located on an embankment just east of the main yard in Belleville, as seen in Plate B.8. The embankment crest was noted to be at least 3 m (10 ft) above the surrounding ground. Both the slag ballast and ties were in reasonable condition. As seen in Plate B.9, there was geotextile material showing at the surface next to the switch, indicating that the excess material had been draped along the walls of the prepared trench. The local personnel stated that two pieces of material with an overlap along the track centre had been installed in the wider section of the switch. Sudbury slag ballast was used below the switch. This is a very hard-mineral tough ballast which should offer excellent support. Unfortunately, little consideration appeared to have been given to drainage of the ballast. It is unlikely that water can drain easily through the embankment soil which crested level with the shoulder ballast since the edges of the geotextile were turned up to the surface. Without lateral drainage, the coarse ballast will harbour the surface water under the switch, allowing it to seep into the trackbed rather than to flow out to the surface ditch.

B.5 KINGSTON SUBDIVISION, MP 221.34,
Geddes St., Belleville

Background Information:

type of installation: grade-crossing
fabric installed: Bidim C-38, 340 g/m² (10 oz/yd²)
date of installation: 1980
estimated tonnage: 16.1 million gross tonnes per year
(17.7 MMGT)
additional notes: two tracks, subgrade soil mapped in Elmbrook
Group, a greyish-brown clay, imperfect
drainage

Site Information:

date of visit: June 10, 1981
weather conditions: overcast and raining

The Geddes Street grade-crossing was established in a cut section of track, as seen in Plate B.10. Bulk subgrade and ballast samples were taken for sieve analyses. As seen in Plate B.11, the geotextile was visible on the surface at both sides of the south track. The slag ballast was in reasonable condition at the crossing (approximately 11 per cent smaller than 5 mm or No. 4 sieve size). Both tracks appeared to be holding up well under the traffic load. The drainage ditch bottom was approximately 1 m (3.3 ft) below the track level but unfortunately had insufficient grade, as seen in Plate B.10. Water was standing in the ditches, indicating a relatively high water table.

The laboratory tests on the bulk samples gave the following results:

- subgrade from north slope of cut (beyond ditch)
mainly sand and gravel with some silt
- field m/c = 8.8 per cent
- 100 per cent passing 37 mm sieve
- 78 per cent passing 19 mm sieve
- 58 per cent passing 10 mm sieve
- 44 per cent passing 5 mm sieve
- 30 per cent passing 0.6 mm sieve
- 20 per cent passing 0.06 mm sieve
- 10 per cent less than 0.006 mm sieve.

The Ballast Sample was of Sudbury Slag:

- . field m/c = 0.9 per cent
- . 100 per cent passing 50 mm sieve
- . 89 per cent passing 37 mm sieve
- . 56 per cent passing 19 mm sieve
- . 25 per cent passing 10 mm sieve
- . 11 per cent passing 5 mm sieve
- . 3 per cent passing 0.6 mm sieve.

B.6 ALEXANDRIA SUBDIVISION, MP 22.29,
McCormick Road, Alexandria

Background Information:

type of installation: grade-crossing
fabric installed: Bidim C-34, 270 g/m² (8 oz/yd²)
date of installation: 1980
estimated tonnage: 11.9 million gross tonnes per year
(13.2 MMGT)
additional notes: subgrade soil mapped in Eamer Loan Group,
medium textured till with good drainage
underlain by a varved clay, with poor
drainage

Site Information:

date of visit: June 23, 1981
weather conditions: clear and cool, rain overnight, most fields
and ditches are ponding water

The McCormick Road crossing, as seen looking westward along the track, is shown in Plate B.12. The track is elevated above the ground to the south of the track. There was a wide, flat surface along the north side of the track, level with the base of the ties. The embankment drops about 2 m (6.6 ft) to the ditch line along the south side of the track. The Sudbury slag ballast was beginning to foul on both sides of the crossing. Vegetation was evident in the central section of the track about 8 m (26.6 ft) beyond the ends of the crossing, indicating that approximately 25 m (83 ft) of track had been undercut and cleaned. The ballast was badly fouled beyond these limits. Subsurface drain pipes had been used in the installation to help channel the water in the crossing to the shoulder ditches, as illustrated by Plate B.13.

B.7 ALEXANDRIA SUBDIVISION, MP 58.70,
Township Road, Vars

Background Information:

type of installation:	grade crossing
fabric installed:	Bidim C-34, 270 g/m ² (8 oz/yd ²)
date of installation:	1980
estimated tonnage:	11.9 million gross tonnes per year (13.2 MMGT)
additional notes:	subgrade soil mapped in Upland Sand Group, loose fine sand, good drainage

Site Information:

date of visit:	June 23, 1981
weather conditions:	clear and cool, rain overnight

The track structure was built on a small embankment, approximately 1.5 m (5 ft) high. The track adjacent to either side of the crossing was pumping, with the east side more severe than the west. The ballast on top of the Bidim C-34 was Sudbury slag which had turned a muddy brown on the east side of the crossing from pumping fines, as seen in Plate B.14. Puddles had formed on the surface next to the crossing. Drainage pipes had been installed and extend out from the embankment into the ditches, indicating that there had been an attempt to channel the water from the crossing out to the shoulders. There was at least a depth of 600 mm (2 ft) of standing water in the drainage ditches near the crossing, as seen in Plate B.15. It is evident that the geotextile, after only a year in service, was not functioning very well at this crossing.

B.8 ALEXANDRIA SUBDIVISION, MP 65.93,
Carlsbad Springs No.1

Background Information:

type of installation: grade crossing
fabric installed: Bidim C-34, 270 g/m² (8 oz/yd²)
date of installation: 1980
estimated tonnage: 11.9 million gross tonnes per year
(13.2 MMGT)
additional notes: subgrade soil mapped in Bearbrook, Clay
Group, poor drainage

Site Information:

date of visit: June 23, 1981
weather conditions: sunny and warm

The track structure was about 2 m (6.6 ft) above the surrounding ground surface, as shown in Plate B.16. The Sudbury slag ballast was beginning to show signs of fouling near the crossing. As shown in Plate B.17, there were drain pipes extending out from the embankment into the ditches to assist the subsurface drainage of the crossing. The site appeared to be draining reasonably well under the circumstances. Water was standing in the ditch at the base of the crossing embankment.

B.9 ALEXANDRIA SUBDIVISION, MP 67.44,
Carlsbad Springs No.2

Background Information:

type of installation:	grade-crossing
fabric installed:	Bidim C-34, 270 g/m ² (8 oz/yd ²)
date of installation:	1980
estimated tonnage:	11.9 million gross tonnes per year (13.2 MMGT)
additional notes:	subgrade soil mapped between Bearbrook Clay, having poor drainage, and Upland Sand having good drainage

Site Information:

date of visit:	June 23, 1981
weather conditions:	sunny and warm

As shown in Plate B.18, there were two tracks at this crossing, a mainline track seen on the left (north) and a siding. The mainline track had recently received some upgrading prior to the visit. The topography was flat and there did not appear to be standing water present in the ditches at this site. A view along the mainline track is shown in Plate B.19, where it is seen that the shoulder drops off to a shallow ditch. There was pumping track approximately 9 m (30 ft) east of the crossing which was excessive at the track joints. Closer to the crossing, the ties were in good shape but the slag ballast was starting to foul. There were no subsurface drain pipes at this installation.

B.10 ALEXANDRIA SUBDIVISION, MP 68.94,
Carlsbad Springs No.3

Background Information:

type of installation: grade-crossing
fabric installed: Bidim C-34, 270 g/m² (8 oz/yd²)
date of installation: 1981
estimated tonnage: 12.0 million gross tonnes per year
(11.9 MMGT)
additional notes: subgrade soil mapped in Bearbrook Clay Group,
poor drainage

Site Information:

date of visit: June 23, 1981
weather conditions: sunny and warm

As shown in Plate B.20, the track was in a relatively flat, wooded area, similar to the grade-crossing at MP 67.44. There were shallow ditches at this crossing offset about 1 m (3.3 ft) from the ends of the ties close to the crossing. Away from the crossing the ditches were considerably further away from the tie ends, as may be seen in Plate B.20. The extent of the installation was clearly defined, since the existing Dolomite ballast had been replaced by Sudbury slag. The new ballast did not appear to be fouled after one year of service. On the other hand, the old Dolomite ballast was badly fouled at numerous points along the track surface, as seen in Plate B.21. The rehabilitation of the crossing included perforated drain pipes which left the track at the ends of the reballasted surface, 11 m (37 ft) west of the crossing and 6 m (20 ft) east of the crossing.

B.11 DUNDAS SUBDIVISION, MP 73.97,
Clarke Sideroad, London

Background Information:

type of installation:	grade crossing
fabric installed:	Terrafix 300N, 500 g/m ² (14.6 oz/yd ²)
date of installation:	1976
estimated tonnage:	15.2 million gross tonnes per year (16.7 MMT)
additional notes:	regular maintenance every six months prior to installation, returned in 1980 to upgrade track again; subgrade soil mapped in London Loam Group, till, poor to good drainage

Site Information:

date of visit: June 29, 1981
weather conditions: sunny and warm, no rain for the past two days

A general view of the crossing is shown in Plate B.22. The two main-line tracks were situated on very flat ground. There were no ditches adjacent to the crossing. It appears that during installation of the geotextile the dirty ballast that was removed from below the tracks was placed within the right-of-way and levelled off. This has caused additional drainage problems at the site. As seen in Plate B.23, the base of the ties were at the ground level, indicating that any geotextile installed below the bottom of the ties could not help stabilize the subgrade with lateral drainage. The Sudbury slag which was placed in 1980 did not show any fouling at the surface.

B.12 MASSENA SUBDIVISION, MP 52.13,
Highway No. 4, Ormstown

Background Information:

type of installation: grade-crossing
fabric installed: Texel 7616, 520 g/m² (15.1 oz/yd²)
date of installation: 1980
estimated tonnage: 1.7 million gross tonnes per year (1.8 MMGT)
additional notes: no data available

Site Information:

date of visit: July 14, 1981
weather conditions: overcast, cool

The general conditions at the site are shown in Plate B.24. The grade-crossing is elevated about 3 m (10 ft) above the surrounding ground surface. The installation, completed a year prior to the visit, has not experienced any visible form of degradation. A view of the crossing is shown in Plate B.25. The annual tonnage was relatively low in comparison to the other sites visited. The drainage conditions at the crossing have been aided by the deep ditches at the shoulders. There was some movement of the ties and rails evident beyond each end of the geotextile, but generally the track was in good condition.

B.13 NAPADOGAN SUBDIVISION, MP 200.0-200.5,
east of Quisibis

Background Information:

type of installation:	upgrading mainline track
fabric installed:	Terrafix 300NA, 500 g/m ² (14.6 oz/yd ²)
date of installation:	1978
estimated tonnage:	12.3 million gross tonnes per year (13.5 MMGT)
additional notes:	installed during undercutting, track is situated beside the St. John River, fluvial deposit, soft subgrade soil, poor drainage

Site Information:

date of visit:	July 16, 1981
weather conditions:	sunny and warm

Plate B.26 illustrates the general conditions at MP 200 facing south-east. The track was constructed on an embankment for bearing-capacity and flood reasons. It was located between the Trans-Canada Highway and the St. John River. Water flowing to the river must pass the highway embankment and then pass the railway embankment. Some of this water was trapped between the two embankments, softening the subgrade soil.

The track had recently been repaired from a derailment; therefore, it was difficult to assess the performance of the geotextile from the surface appearance. The shoulders of the embankment were wide, which means long drainage paths for the lateral flow of water. The embankment was partially built of wood chips, a typical method of embankment weight reduction on soft soils. The ballast particles were dirty on the surface but the source of the dirt was not apparent. There were two private crossings at about MP 200.1 and MP 200.4 where the track could be accessed for further investigations. The surficial track condition at MP 201.0, beyond the geotextile installation, was not noticeably different from the section with the geotextile in-track.

Typical topographical conditions looking towards the southwest and northwest sides of the track near MP 200.1 are shown in Plates B.27 and B.28, respectively, while Plate B.29 shows conditions near MP 200.0 facing northwest. As a comparison, track conditions looking northwest at MP 201.0 where no geotextile was installed are shown in Plate B.30.

B.14 NAPADOGAN SUBDIVISION, MP 203.20,
A Side Road, Quisibis

Background Information:

type of installation:	grade crossing
fabric installed:	Terrafix 300NA, 500 g/m ² (13.6 oz/yd ²)
date of installation:	1978
estimated tonnage:	12.3 million gross tonnes per year (13.5 MMGT)
additional notes:	no data available

Site Investigation:

date of visit:	July 16, 1981
weather conditions:	sunny and warm

Plate B.31 shows a general view looking northeast at this site. There were two tracks at the crossing, the mainline track and a siding. The highway and railway embankments were divided by a ditch approximately 1 m (3.3 ft) deep. The mainline track was situated between the highway and the siding. There were no visible signs of subsurface drainage at the site. Plate B.32 shows a general view looking southeast. The ballast section between the two tracks at this crossing, which is shown in Plate B.32, was not fouled. The crossing was relatively good; however, it is understood that the track had received maintenance just prior to the visit.

B.15 NAPADOGAN SUBDIVISION, IP 204.78,
A Side Road, Quisibis

Background Information:

type of installation:	grade-crossing
fabric installed:	Terrafrax 300NA, 500 g/m ² (13.6 oz/yd ²)
date of installation:	1978
estimated tonnage:	12.3 million gross tonnes per year (13.5 MGT)
additional notes:	no data available

Site Information:

date of visit: July 16, 1981
weather conditions: sunny & warm

This site, photographed from the southeast looking northwest, is shown in Plate B.33. It was a secondary road level-crossing at MP 204.78, situated beside the Trans-Canada Highway. The track structure was built slightly above the surrounding ground and was isolated by shallow ditches. A close-up view of the track, which is shown in Plate B.34, indicates that the crossing was in good shape. The ties had not penetrated the ballast and the rails were not out of alignment. It should be noted that the ballast and tie gangs had recently upgraded the track in this area just prior to the site visit.

B.16 NAPADOGAN SUBDIVISION, MP 204.78
Private Crossing, west of the
Pacific Junction (Moncton, N.B.)

Background Information:

type of installation:	grade-crossing
fabric installed:	Terrafix 300NA, 500 g/m ² (13.6 oz/yd ²)
date of installation:	1979
estimated tonnage:	12.4 million gross tonnes per year (13.6 MMT)
additional notes:	no data available

Site Information:

date of visit:	July 17, 1981
weather conditions:	sunny and warm

The general site conditions are shown in Plate B.35, which involves a former private logging road. The road was constructed of a sandy silt which had been hard packed, limiting the drainage of water at the crossing. The track structure was built on a small embankment and appeared to be sufficiently drained. It is understood that during the wet season the crossing was pumping fine soil material to the surface prior to the installation of a geotextile. The geotextile was installed under the crossing as an experiment to see if the problem could be corrected.

After two years of service and about 24.4 million gross tonnes (27 MMT), the crossing was in good condition, as seen in Plate B.36. The shoulder ditches were about 1 m (3.3 ft) deep and they were about 1 m (3.3 ft) away from the end of the ties. The condition under the grade-crossing planks is not known but there were no fines visible at the ends of the crossing. The geotextile appears to have helped drain the crossing of water and to have retained the fines.

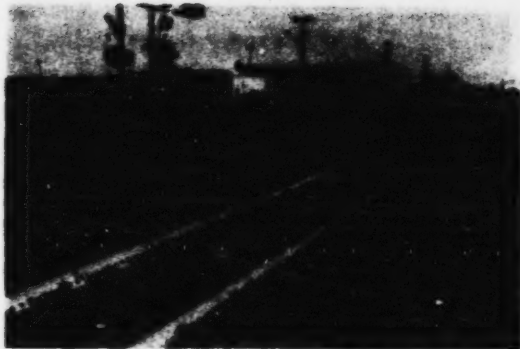


Plate B.1 General view of grade crossing taken from north of tracks, looking west (Oakville Subdivision MP 21.96)

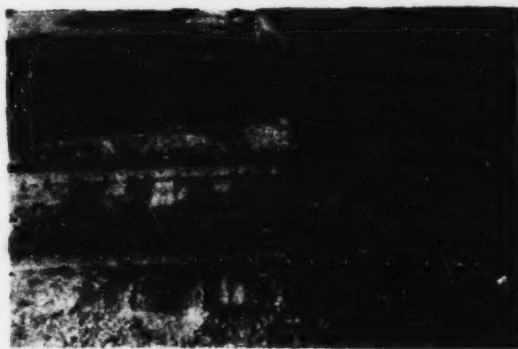


Plate B.2 Submerging ties and running rail of lower (north) track resulting from poor drainage (Oakville Subdivision MP 21.96)



Plate B.3 General view looking east along eastbound main line, showing flat terrain and two siding tracks on south side (Oakville Subdivision MP 24.42)



Plate B.4 Poor surface drainage conditions for eastbound main line (Oakville Subdivision MP 24.42)



Plate B.5 General view of crossing looking east, showing flattish nature of surrounding terrain (Kingston Subdivision MP 218.18)



Plate B.6 Shallow drainage conditions at southeast shoulder of crossing (Kingston Subdivision MP 218.18)

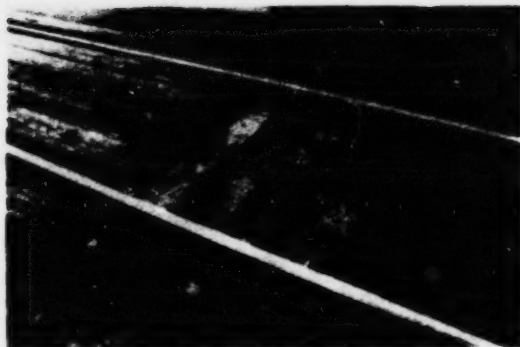


Plate B.7 Fouled ballast on surface of north-west corner of crossing (Kingston Subdivision MP 218.18)



Plate B.8 Geotextile installation at east switch, track 3 (Kingston Subdivision MP 218.18)

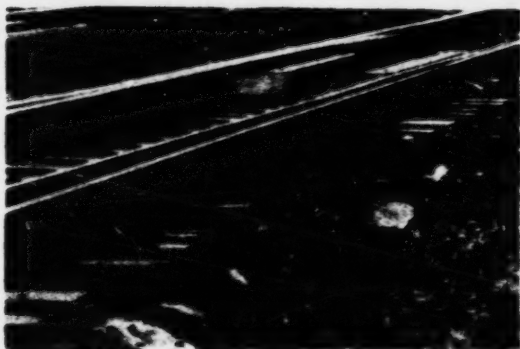


Plate B.9 Close-up view of switch (Kingston Subdivision MP 218.18)



Plate B.10 Track conditions in cut section (Kingston Subdivision MP 221.34)



Plate B.11 Geotextile with turned down ends beyond crossing to facilitate lateral drainage through geotextile (Kingston Subdivision MP 221.34)



Plate B.12 General site conditions showing extensive ballast fouling beyond rehabilitated crossing (Alexandria Subdivision MP 22.29)

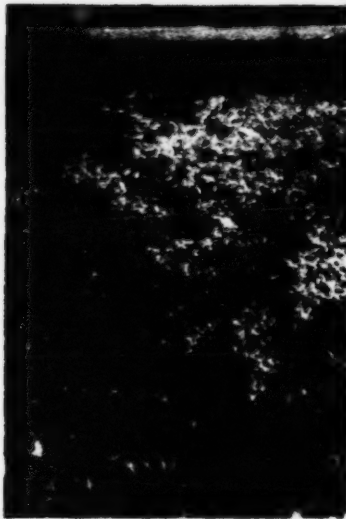


Plate B.13

View of track
shoulder with
perforated
drain pipes
(Alexandria
Subdivision MP
22.29)



Plate B.14 General view showing fouled ballast
conditions on east side of grade
crossing (Alexandria Subdivision MP
58.70)



Plate B.15 Drainage conditions on west side of
grade crossing which was showing
less ballast fouling than on east
side (Alexandria Subdivision MP
58.70)



Plate B.16 Drainage conditions at grade
crossing showing pumping track
beyond rehabilitated area
(Alexandria Subdivision MP 65.93)

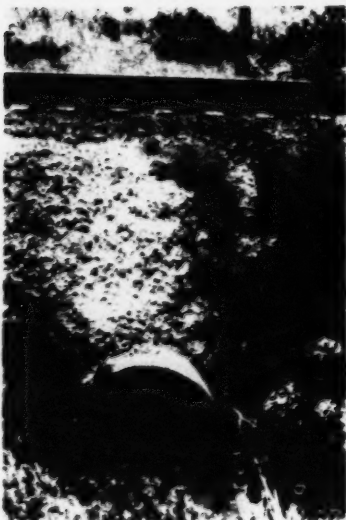


Plate B.17

View of track
shoulder with
perforated
drain pipe
(Alexandria
Subdivision
MP 65.93)

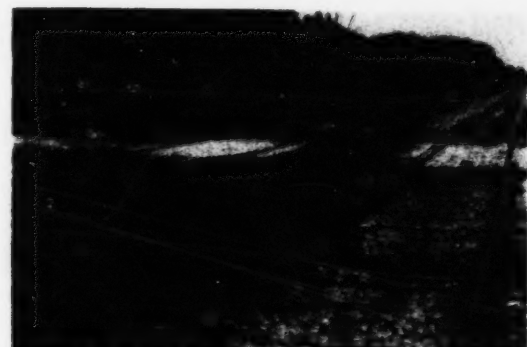


Plate B.18 Conditions of upgraded main line
(left) track (Alexandria Subdivi-
sion MP 67.44)



Plate B.19

View of track
shoulder and
drainage con-
ditions at
grade crossing
with obvious
pumping beyond
crossing
(Alexandria
Subdivision MP
67.44)

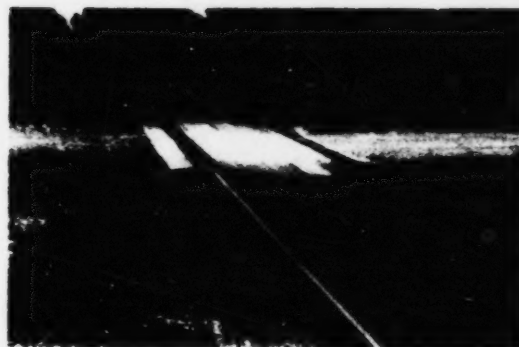


Plate B.20 Flat terrain at grade crossing and
along track (Alexandria Subdivision
MP 68.94)

Plate B.21
Pumping track
conditions
just beyond
grade crossing
(Alexandria
Subdivision MP
68.94)

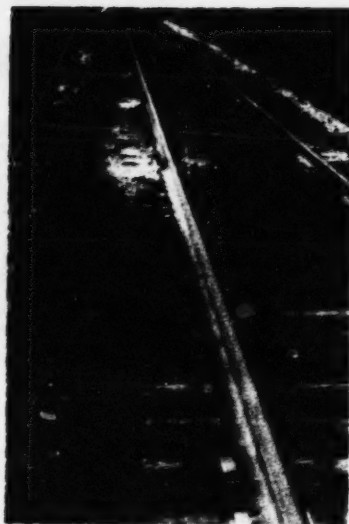


Plate B.22 General site conditions at Clarke
Side Road grade crossing (Dundas
Subdivision MP 73.97)

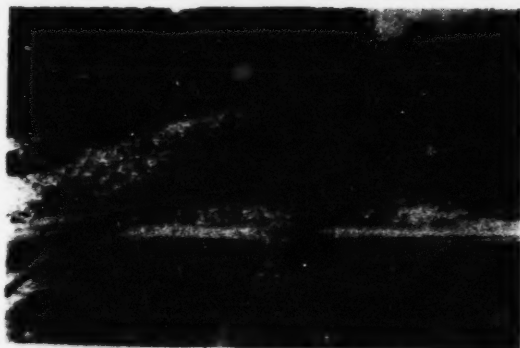


Plate B.23 Close-up of track which was later
selected for test pit excavations
(Dundas Subdivision MP 73.97)



Plate B.24 General site conditions at Massena
grade crossing (Massena Subdivision
MP 52.13)

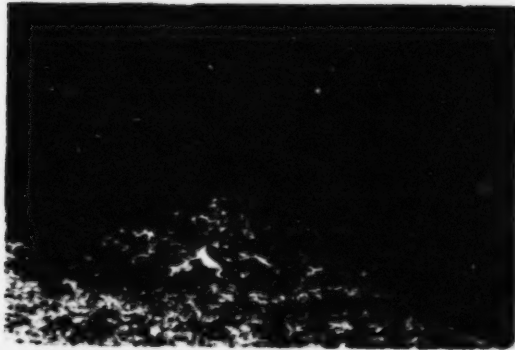


Plate B.25 Close-up view of crossing showing geotextile in foreground (Massena Subdivision MP 52.13)

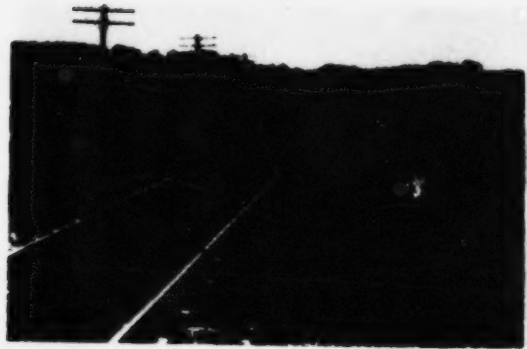


Plate B.26 General conditions looking southeast along track (Napadogan Subdivision MP 200.0)



Plate B.27 Southwest view of track embankment and ditch from northeast side (Napadogan Subdivision near MP 200.1)



Plate B.28 Northwest view of track embankment and ditch from southeast side (Napadogan Subdivision near MP 200.1)



Plate B.29 General conditions at MP 200 looking northwest along track (Napadogan Subdivision MP 200)



Plate B.30 General conditions at MP 201 looking northwest along track (Napadogan Subdivision MP 201)

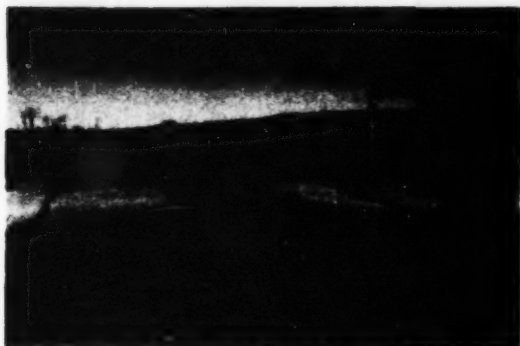


Plate B.31 General view of grade crossing on main tracks (right) looking northeast (Napadogan Subdivision MP 203.20)



Plate B.32 General view of track conditions looking to the southeast with main line on left (Napadogan Subdivision MP 203.20)



Plate B.33 General site conditions at minor road crossing (Napadogan Subdivision MP 204.78)



Plate B.34 Close-up view of ballast condition at minor road crossing (Napadogan Subdivision MP 204.78)



Plate B.35 General site conditions at logging road crossing (Napadogan Subdivision MP 204.78)

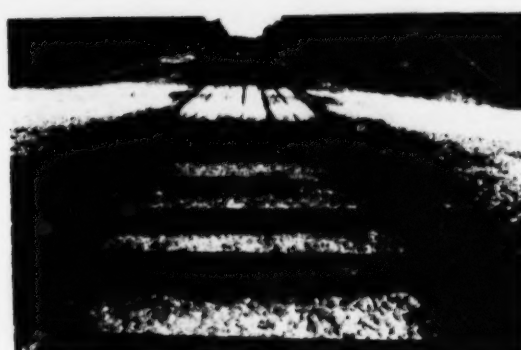


Plate B.36 Close-up view of ballast condition at logging road crossing (Napadogan Subdivision MP 204.78)

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